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Technical Report CERC-94-5
April 1994

US Army Corps of Engineers
Waterways Experiment Station

Noyo River and Harbor, California, Design for Harbor Entrance Protection

Coastal Model Investigation

by Robert R. Bottin, Jr.

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Prepared for U.S. Army Engineer District, San Francisco

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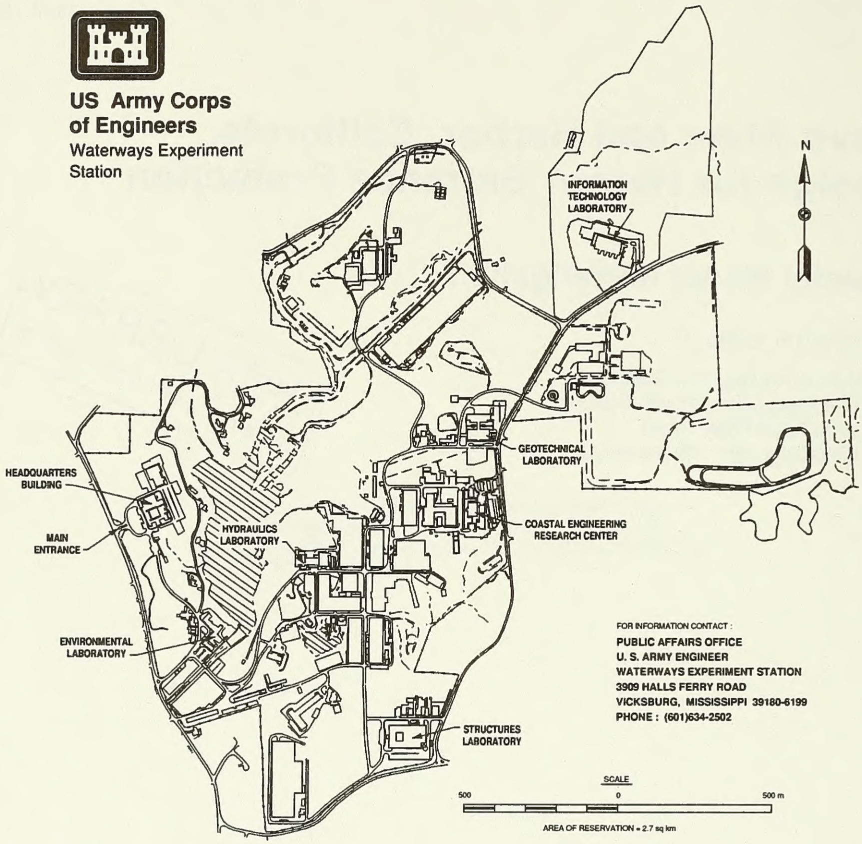

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Contents

Preface

A request to reactivate and conduct additional testing on the existing Noyo River and Harbor model was initiated by the U.S. Army Engineer District, San Francisco (SPN). Authorization for the U.S. Army Engineer Waterways Experiment Station's (WES) Coastal Engineering Research Center (CERC) to perform the study was subsequently granted, and funds were authorized by SPN on 8 June 1992, 11 January 1993, and 15 December 1993.

Model testing was conducted at WES intermittently during the period from December 1992 through January 1994 by CERC personnel under the direction of Dr. James R. Houston and Mr. Charles C. Calhoun, Jr., Director and Assistant Director, CERC, respectively; and under the direct supervision of Messrs. C. E. Chatham, Jr., Chief, Wave Dynamics Division, and Dennis G. Markle, Chief, Wave Processes Branch (WPB). The tests were conducted by Messrs. Hugh F. Acuff and Larry R. Tolliver and Ms. Bettye E. Stephens, Civil Engineering Technicians, and Mr. Joe Trâhan, contract student, under the supervision of Mr. Robert R. Bottin, Jr., Research Physical Scientist. This report was prepared by Mr. Bottin.

During the course of the investigation, liaison was maintained by means of conferences, telephone conversations, and monthly progress reports. Messrs. Jeff Cole and Joe Hooks, SPN, visited WES to observe model operation during the course of the study, and Mr. Bottin visited the SPN office and the city of Fort Bragg, California, prior to the initial investigation.

Initial test results for the model were reported in WES Technical Report CERC-88-15, "Noyo River and Harbor, California, Design for Wave and Surge Protection; Coastal Model Investigation," dated September 1988. Results for additional tests were reported in WES Technical Report CERC-89-18, "Noyo River and Harbor, California, Design for Wave Protection, Supplemental Tests; Coastal Model Investigation," dated December 1989.

Dr. Robert W. Whalin was Director of WES during model testing and the preparation and publication of this report. COL Bruce K. Howard, EN, was Commander.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048	meters
miles (U.S. statute)	1.609347	kilometers
square feet	0.09290304	square meters
square miles (U.S. statute)	2.589998	square kilometers

1 Introduction

The Prototype

Noyo River and Harbor are located on the California coast in Mendocino County, approximately 135 miles[1] north of San Francisco and 87 miles south or Eureka (Figure 1). The shoreline in the locality consists of broken, irregular cliffs about 40 to 80 ft high with numerous rocks extending several hundred yards offshore. Small pocket beaches are found at the heads of coves in the immediate vicinity. The Noyo River empties into Noyo Cove, which is approximately 1,800 ft wide, north to south, and 2,000 ft long, east to west.

The existing Noyo River and Harbor project was authorized by the River and Harbor Act of 1930 (U.S. Army Engineer District (USAED), San Francisco 1979), and construction was completed in 1961. It consists of a jettied entrance at the river mouth; a 10-ft-deep, 100-ft-wide entrance channel; and a 10-ft-deep, 150-ft-wide river channel extending upstream about 0.6 mile. Noyo Mooring Basin is located on the south bank of the river at the upstream limit of the dredged river channel. Further upstream, approximately 1.1. miles from the river mouth, a privately owned harbor (Dolphin Marina) is located on the south bank. An aerial photograph of the area is shown in Figure 2.

The Problem

Noyo Cove is open to the Pacific Ocean and is exposed to large waves generated by local coastal storms accompanied by strong winds (sea) and distant ocean storms with and without local winds (swell). Waves in excess of 20 ft in height approach the cove from the southwest clockwise through northwest directions. Heavy seas sweep across the cove and

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[1] A table of factors for converting non-SI units of measurements to SI units is presented on page v.

Figure 1. Project location

through the jettied river entrance, making them impassable for entry or departure during these periods. In addition to these adverse wave conditions, the harbor has experienced strong surging problems due to long-period wave energy resulting in damages to small craft moored there. Shoaling in the river channel also occurs due to the deposition of material brought down the river during the winter rainy season. This causes navigational difficulties in the shallow river channel, particularly upstream of Noyo Harbor. Vessels are subject to damage by grounding and are forced to wait for favorable tide conditions to provide adequate depths.

Improvements at Noyo River and Harbor would result in the reduction of boat and harbor damages, a harbor of refuge for vessels during storm activity, increased commercial fish catch, and increases in recreational boating. The project construction would employ local (currently unemployed) labor and enhance area redevelopment. The improvements should also improve the overall commercial fishing operation, thereby contributing to the local economic base.

Figure 2. Aerial view of prototype site

Proposed Improvements

Authorization for improvements at Noyo River and Harbor was granted by the River and Harbor Act of 1962. Under this authorization, however, breakwaters were proposed to protect the outer cove for development. The massive breakwaters required were not economically feasible (due to the high cost of construction and maintenance), resulting in the project's being transferred to an inactive category. The Water Resources Development Act (WRDA) of 1976 modified the 1962 project to provide for construction of up to two breakwaters without a specific location to protect the harbor entrance (USAED, San Francisco 1979). The location of breakwaters in more shallow water would reduce construction cost significantly. The 1976 WRDA also included additional channel improvements (deepening, widening, and extending) as deemed necessary, subject to applicable economic and environmental criteria.

Previously Reported Model Tests and Conclusions

The Noyo River and Harbor model was constructed initially to investigate both short- and long-period wave and river-flow conditions in the river and harbor for comprehensive test conditions. Qualitative information on the effects of the proposed breakwaters on sediment moving down the river also was provided. Details of the investigation were published in Bottin, Acuff, and Markle (1988). Conclusions derived from results of these tests are mentioned below. Plan numbers in the following subparagraphs refer to the previous investigation.

a. Existing conditions are characterized by very rough and turbulent wave conditions in the Noyo River entrance during periods of storm wave attack.

b. Deepening of the entrance channel will not improve wave conditions in the existing river entrance, considering all test conditions.

c. The originally proposed breakwater location (Plan 3) resulted in excessive wave heights (up to 8.8 ft) in the river entrance.

d. Of the 40 expedient rubble-mound breakwater plans (Plans 5 through 42) tested, the alignment of the 637-ft-long breakwater of Plan 39 appeared to be optimum with regard to wave protection, navigation, and economics.

e. The 637-ft-long dolosse breakwater of Plan 43 (same alignment as Plan 39) was selected as the optimum improvement plan for protection of the Noyo River entrance.

f. The breakwater configuration of Plan 43 will result in improved surge conditions due to long-period wave energy in Noyo River and Harbor.

g. The breakwater configuration of Plan 43 will not interfere with the movement of riverine sediment seaward into Noyo Cove; however, the structure will direct sediment to the northern portion of the cove.

The Noyo River and Harbor model was reactivated to determine the optimum breakwater plan that would provide the fishing fleet protection from hazardous wave conditions while traveling through the jettied entrance. The breakwater plan was developed for 14-ft design waves, as opposed to waves up to 32 ft in the initial study. During storm conditions above a certain threshold (approximately 14-ft waves) fishermen presumably do not go out to fish; therefore, there are fewer benefits for protecting the entrance under these extreme conditions. Most benefits would be derived for wave conditions with heights of 14 ft or less. Details of the supplement tests were published in Bottin and Mize (1989). Conclusions based on results of these tests are listed below. Plan numbers refer to the supplemental investigation.

a. Existing conditions are characterized by very rough and turbulent wave conditions in the Noyo River jettied entrance for 15-sec, 14-ft incident design wave conditions. Waves with maximum heights ranging from 9.3 to 11.7 ft will occur in the entrance, depending on direction of wave approach.

b. Of the test plans involving a shore-connected outer north breakwater and a detached inner breakwater (Plans 1 through 14), Plan 14 (300-ft-long outer and 250-ft-long inner breakwaters) will meet the established 6.0-ft wave-height criterion in the existing entrance for design wave conditions from all directions. Wave heights in the entrance for waves from the predominant west-northwest direction will be 3.5 ft or less.

c. Incremental removal of the Plan 14 outer breakwater (Plans 27 through 31) indicated that the 250-ft-long inner breakwater alone (Plan 31) would meet the established criterion for design wave conditions from all directions. Wave heights up to 5.8 ft will exist in the entrance for waves from the predominant west-northwest direction.

d. Neither the outer shore-connected north breakwater and outer detached south breakwater (Plan 15) nor the outer detached south breakwater plans (Plans 16 through 18) will meet the established wave-height criterion for design wave conditions. Maximum wave heights will range from 7.4 to 11.2 ft in the existing entrance for these plans.

e. Of the improvement plans involving a curved breakwater seaward of the existing entrance (Plans 19 through 22), the 450-ft-long

structure of Plan 22 will meet the established wave-height criterion for design wave conditions from all directions. Maximum wave heights of 6.0 ft will exist in the entrance for waves from the predominant west-northwest direction.

f. Of the improvement plans involving two inner detached breakwaters (Plans 23 through 26), the 375-ft-long north structure and 250-ft-long south breakwater (Plan 26) will meet the established wave-height criterion in the entrance for design wave conditions from all directions. Wave heights in the existing entrance will be up to 5.8 ft for waves from the predominant west-northwest direction.

Subsequent to testing of the supplemental tests, a conference was held at the U.S. Army Engineer Waterways Experiment Station (WES) Coastal Engineering Research Center (CERC) with representatives in attendance from Noyo Harbor, the U.S. Army Engineer Division, South Pacific (CESPD), and the U.S. Army Engineer District, San Francisco (CESPN). Wave height tests were conducted for an outer offshore breakwater configuration provided by CESPN. Breakwaters were constructed expeditiously with mixed stone, and wave height tests were conducted for 11 test plan configurations (Bottin 1989). A plan which included a 400-ft-long structure located in the cove approximately 2,000 ft from the river entrance looked promising; however, test results indicated there would be periods when 14-ft-high incident waves would exceed the 6.0-ft criterion and break in the entrance.

Purpose of the Current Investigation

The Noyo River and Harbor model was reactivated at the request of CESPN to refine the design of the 400-ft-long offshore structure tested during the 1989 conference. A breakwater with the appropriate transmission characteristics was installed and subjected to a wide range of wave conditions. The impact of the structure on long-period wave conditions in the harbor and on wave-induced and riverine bed-load sediment patterns also was evaluated for the optimized structure.

Wave-Height Criterion

Completely reliable criteria have not yet been developed for ensuring satisfactory navigation and mooring conditions in small-craft harbors during attack by waves. For this study, however, CESPN specified that for an improvement plan to be acceptable, maximum significant wave heights were not to exceed 6.0 ft in the existing Noyo River jettied entrance for incident wave heights of 14 ft or less.

2 The Model

Design of Model

The Noyo River and Harbor model (Figure 3) was constructed to an undistorted linear scale of 1:75, model to prototype. Scale selection was based on such factors as:

a. Depth of water required in the model to prevent excessive bottom friction.

b. Absolute size of model waves.

c. Available shelter dimensions and area required for model construction.

d. Efficiency of model operation.

e. Available wave-generating and wave-measuring equipment.

f. Model construction costs.

A geometrically undistorted model was necessary to ensure accurate reproduction of wave and current patterns. Following selection of the linear scale, the model was designed and operated in accordance with Froude's model law (Stevens et al. 1942). The scale relations used for design and operation of the model are shown in the following tabulation:

Characteristic	Dimension[1]	Model-Prototype Scale Relations
Length	L	$L_r = 1:75$
Area (A)	L^2	$A_r = L_r^2 = 1:5,625$
Volume	L^3	$\cancel{V}_r = L_r^3 = 1:421,875$
Time	T	$T_r = L_r^{1/2} = 1:8.66$
Velocity	L/T	$V_r = L_r^{1/2} = 1:8.66$
Roughness (Manning's coefficient n)	$L^{1/6}$	$n_r = L_r^{1/6} = 1:2.054$
Discharge (Q)	L^3/T	$Q_r = L_r^{5/2} = 1:48,714$

[1] Dimensions are in terms of length (L) and time (T).

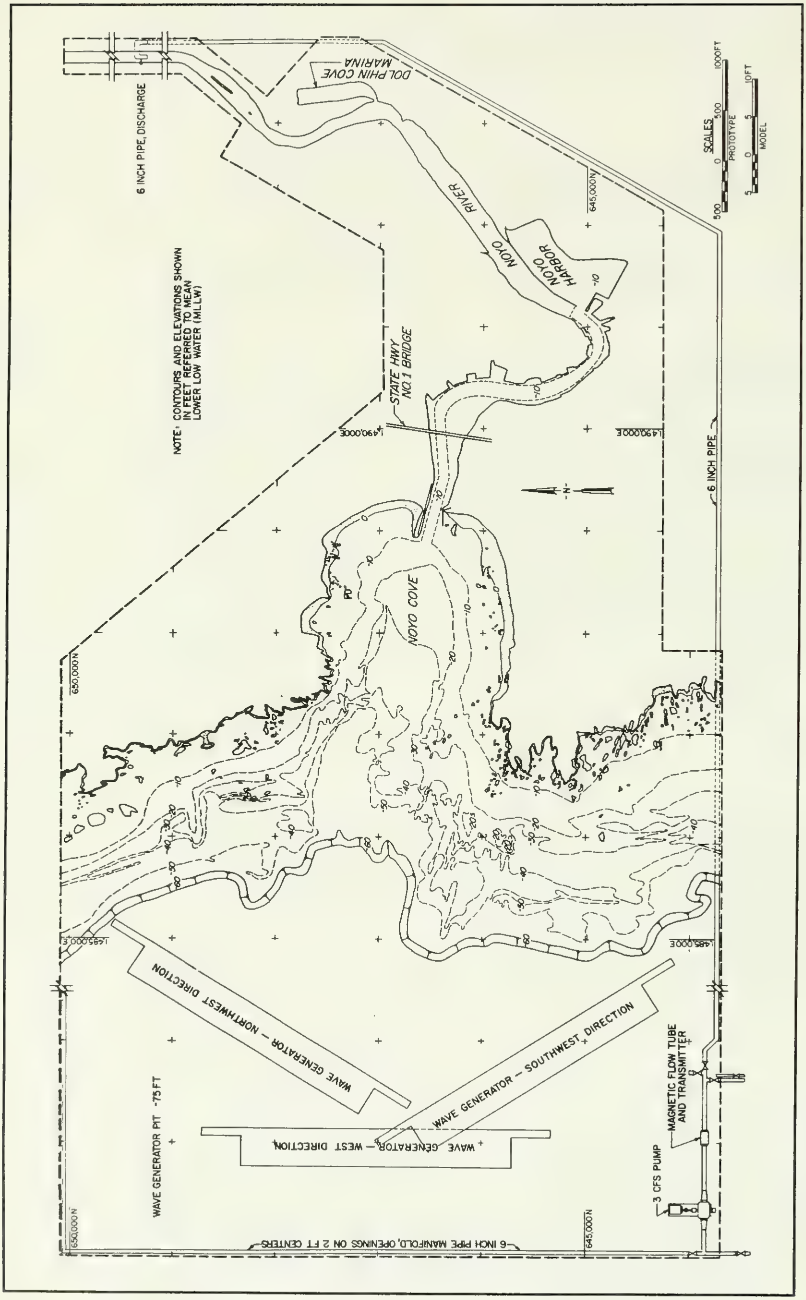

Figure 3. Model layout

The proposed breakwaters at Noyo included the use of concrete armor units (Accropodes). Since the porosity of these armor units differs from that of rock and since the units could not be reproduced to scale (due to cost and time requirements), two-dimensional wave transmission tests were conducted at a scale large enough to have negligible scale effects (i.e., 1:43) to determine the correct transmission through the proposed structures. This transmission then was duplicated at a scale of 1:75 using a rock cross section, and the three-dimensional model structures were built accordingly. These tests are detailed in Smith and Hennington (in publication).

Parts of the existing jetties at Noyo River entrance are rubble-mound structures. Experience and experimental research have shown that considerable wave energy passes through the interstices of this type structure; thus, the transmission and absorption of wave energy became a matter of concern in design of the 1:75 scale model. In small-scale hydraulic models, rubble-mound structures reflect relatively more and absorb or dissipate relatively less wave energy than geometrically similar prototype structures (LéMéhauté 1965). Also, the transmission of wave energy through a rubble-mound structure is relatively less for the small-scale model than for the prototype. Consequently, some adjustment in small-scale model rubble-mound structures is needed to ensure satisfactory reproduction of wave-reflection and wave-transmission characteristics. In past investigations (Dai and Jackson 1966, Brasfeild and Ball 1967) at WES, this adjustment was made by determining the wave-energy transmission characteristics of the proposed structure in a two-dimensional model using a scale large enough to ensure negligible scale effects. A section then was developed for the small-scale, three-dimensional model that would provide essentially the same relative transmission of wave energy. Therefore, from previous findings for structures and wave conditions similar to those at Noyo, it was determined that a close approximation of the correct wave-energy transmission characteristics would be obtained by increasing the size of the rock used in the 1:75-scale model to approximately 1.5 times that required for geometric similarity. Accordingly, in constructing the rubble-mound structures in the Noyo River and Harbor model, the rock sizes were computed linearly by scale and then multiplied by 1.5 to determine the actual sizes to be used in the model.

The values of Manning's roughness coefficient, n, used in the design of the main river channel were calculated from water-surface profiles of known discharges in the prototype. From these computations and experience, an n value of 0.030 was selected for use in the main river channel. In addition, based on experience, an n value of 0.050 was selected for overbank roughness. Therefore, based on previous WES investigations (Miller and Peterson 1953, Cox 1973), the various model areas from the Noyo Harbor entrance extending upstream were given finishes that would represent prototype n values of 0.030 and 0.050.

Ideally, a quantitative, three-dimensional, movable-bed model investigation would best determine the effects of the proposed structures with regard to the deposition of sediment at the river mouth and in Noyo Cove.

However, this type of model investigation is difficult and expensive to conduct, and each area in which such an investigation is contemplated must be carefully analyzed. In view of the complexities involved in conducting movable-bed model studies and due to limited funds and time for the Noyo River and Harbor project, the model was modeled in cement mortar (fixed-bed) at an undistorted scale of 1:75, and a tracer material was obtained to qualitatively determine the deposition of riverine sediment (degree of accretion, etc.) at the river mouth for existing conditions and the offshore breakwater plan.

Model and Appurtenances

The model reproduced the lower 15,000 ft of Noyo River, both Noyo Harbor and Dolphin Marina (located on the south bank), Noyo Cove, approximately 5,500 ft of the California shoreline on each side of the river mouth, and underwater topography in the Pacific Ocean to an offshore depth of 60 ft with a sloping transition to the wave generator pit elevation of -75 ft. The total area reproduced in the model was approximately 12,000 sq ft, representing about 2.4 square miles in the prototype. A general view of the model is shown in Figure 4. Vertical control for model construction was based on mean lower low water.[1] Horizontal control was referenced to a local prototype grid system.

Model waves were generated by a 45-ft-long piston-type generator. The horizontal movement of the piston plate caused a periodic displacement of water incident to this motion. The length of the stroke and the frequency of the piston plate movement were variable over the range necessary to generate waves with the required characteristics. In addition, the wave generator was mounted on retractable casters which enabled it to be positioned to generate waves from the required directions.

A water circulation system (Figure 3) consisting of a 6-in. perforated-pipe water-intake manifold, a 3-cfs pump, and a magnetic flow tube and transmitter was used in the model to reproduce steady-state flows through the river channel that corresponded to selected prototype river discharges.

An Automated Data Acquisition and Control System (ADACS), designed and constructed at WES (Figure 5), was used to secure wave-height data at selected locations in the model. Basically, through the use of a minicomputer, ADACS recorded onto magnetic media the electrical output of capacitance-type wave gages that measured the change in water-surface elevation with respect to time. The magnetic media output of ADACS was then analyzed to obtain the wave-height data.

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[1] All elevations (el) cited herein are in feet referred to mean lower low water (mllw) unless otherwise cited.

Figure 4. General view of model

A 2-ft (horizontal) solid layer of fiber wave absorber was placed around the inside perimeter of the model to dampen any wave energy that might otherwise be reflected from the model walls. In addition, guide vanes were placed along the wave generator sides in the flat pit area to ensure proper formation of the wave train incident to the model contours.

As discussed previously, a fixed-bed model was constructed and a tracer material was selected to qualitatively determine the deposition of sediment in Noyo Cove and at the river mouth. Using the prototype sand characteristics (median diameter, D50 = 0.25 mm, specific gravity = 2.69), the tracer was chosen in accordance with the scaling of Noda (1972), which indicates a relation or model law among the four basic scale ratios, i.e., the horizontal scale, l; the vertical scale, m; the sediment size ratio, nD; and the relative specific weight ratio, n'_{γ}. These relations were determined experimentally using a wide range of conditions and bottom materials. Although several types of movable-bed tracer materials were available at WES, previous investigations (Giles and Chatham 1974, Bottin and Chatham 1975) indicated that crushed coal tracer more nearly represented the movement of prototype sand. Therefore, quantities of crushed coal (specific gravity = 1.30; median diameter, D50 = 0.76 mm) were selected for use as a tracer material.

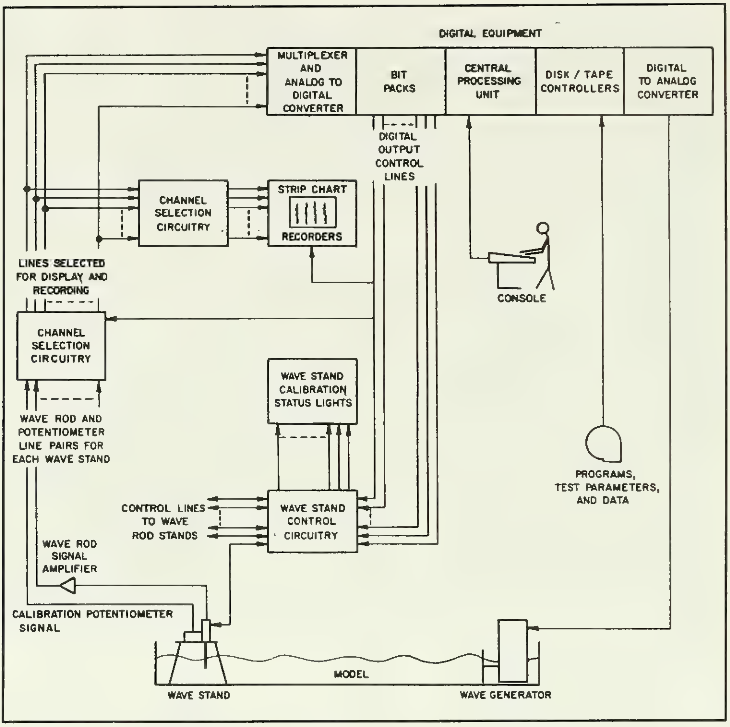

Figure 5. Automated Data Acquisition and Control System

3 Tests Conditions and Procedures

Selection of Test Conditions

Still-water level

Still-water levels (swl's) for wave action models are selected so that the various wave-induced phenomena that are dependent on water depths are accurately reproduced in the model. These phenomena include the refraction of waves in the project area, the overtopping of structures by the waves, the reflection of wave energy from various structures, and the transmission of wave energy through porous structures.

In most cases, it is desirable to select a model swl that closely approximates the higher water stages which normally occur in the prototype for the following reasons:

a.. The maximum amount of wave energy reaching a coastal area normally occurs during the higher water phase of the local tidal cycle.

b. Most storms moving onshore are characteristically accompanied by a higher water level due to wind tide and shoreward mass transport.

c. The selection of a high swl helps minimize model scale effects due to viscous bottom friction.

d. When a high swl is selected, a model investigation tends to yield more conservative results.

The swl's of 0.0 and +7.0 ft were selected by CESPN for use during model tests. The lower value (0.0 ft) represents mllw, and the upper value (+7.0 ft) represents a monthly occurrence at the site. The 0.0-ft swl was used during testing of riverine sediment patterns, and the +7.0-ft swl was

used while testing long-period wave conditions. Both the 0.0- and the +7.0-ft swl's were used for testing short-period storm wave conditions.

Factors influencing selection of test-wave characteristics

In planning the testing program for a model investigation of harbor wave-action problems, it is necessary to select dimensions and directions for the test waves that will allow a realistic test of proposed improvement plans and an accurate evaluation of the elements of the various proposals. Surface-wind waves are generated primarily by the interactions between tangential stresses of wind flowing over water, resonance between the water surface and atmospheric turbulence, and interactions between individual wave components. The height and period of the maximum wave that can be generated by a given storm depend on the wind speed, the length of time that wind of a given speed continues to blow, and the water distance (fetch) over which the wind blows. Selection of test wave conditions entails evaluation of such factors as:

a. The fetch and decay distances (the latter being the distance over which waves travel after leaving the generating area) for various directions from which waves can attack the problem area.

b. The frequency of occurrence and duration of storm winds from the different directions.

c. The alignment, size, and relative geographic position of the navigation entrance to the harbor.

d. The alignments, lengths, and locations of the various reflecting surfaces inside the harbor.

e. The refraction of waves caused by differences in depth in the area seaward of the harbor, which may create either a concentration or a diffusion of wave energy at the harbor site.

Wave refraction

When wind waves move into water of gradually decreasing depth, transformations take place in all wave characteristics except wave period (to the first order of approximation). The most important transformations with respect to selection of test wave characteristics are the changes in wave height and direction of travel due to the phenomenon referred to as wave refraction. The change in wave height and direction is determined by using the numerical Regional Coastal Processes Wave Transformation Model (RCPWAVE) developed by Ebersole, Cialone, and Prater (1986). This model predicts the transformation of monochromatic waves over complex bathymetry and includes refractive and diffractive effects. The model is very efficient for modeling large areas of coastline subjected to

widely varying wave conditions and, therefore, is an extremely useful tool in the solution of many types of coastal engineering problems.

When the refraction coefficient K_r is determined, it is multiplied by the shoaling coefficient K_s to yield a conversion factor for transfer of deepwater wave heights to shallow-water values. The shoaling coefficient, a function of wave length and water depth, can be obtained from the *Shore Protection Manual* (1984).

Refraction and shoaling coefficients and shallow-water directions were obtained at Noyo for various wave periods from five deepwater wave directions (northwest counterclockwise through southwest) and are presented in Table 1. Shallow-water wave directions and refraction coefficients represent an average of the values in the immediate vicinity of the Noyo site (approximately the location of the wave generator in the model). Shoaling coefficients were computed for an 81-ft water depth (75-ft pit elevation with 6-ft tide conditions superimposed) corresponding to the simulated depth at the model wave generator. The wave-height adjustment factor $K_r \times K_s$ can be applied to any deepwater wave height to obtain the corresponding shallow-water value. Based on the refracted directions secured at the approximate locations of the wave generator in the model for each wave period, the following test directions (deepwater direction and corresponding shallow-water direction) were selected for use during model testing.

Deepwater Direction deg	Selected Shallow-Water Test Direction deg
Northwest, 315	300
West-northwest, 292.5	288
West, 270	270
West-southwest, 247.5	254
Southwest, 225	238

Prototype wave data and selection of test waves

Measured prototype wave data on which a comprehensive statistical analysis of wave conditions could be based were unavailable for the Noyo Harbor area. However, statistical deepwater wave hindcast data representative of this area were obtained from the Sea-State Engineering Analysis System (SEAS) by Corson (1985). Deepwater SEAS data are summarized in Table 2. These data were converted to shallow-water values by application of refraction and shoaling coefficients and are shown in Table 3. Characteristics of test waves, wave period and significant wave height, used in the model (selected from Table 3) are shown in the following tabulation:

Deepwater Direction	Selected Test Waves	
	Period, sec	Height, ft
Northwest	7	8, 14, 20
	9	6, 12, 20
	11	6, 14, 24
	13	6, 14, 20
	15	10, 14, 20
	17	6, 12, 22
	19	12
West-northwest	7	8,16
	9	6, 10, 18
	11	6, 14, 24
	13	6, 14, 22
	15	10, 14, 20, 30
	17	10, 20, 28
	19	12, 22
West	7	8,14,20
	9	6, 14, 22
	11	6, 14, 18, 30
	13	6, 14, 20, 30
	15	10, 14, 20, 30
	17	10, 20, 28
West-southwest	7	8, 14, 20
	9	6, 14, 22
	11	10, 14, 20, 30
	13	10, 14, 20, 32
	15	10, 14, 20, 32
	17	14, 20, 28
Southwest	7	8, 14, 20
	9	10, 14, 22
	11	6, 14, 20, 30
	13	10, 14, 20, 32
	15	10, 14, 20, 32
	17	22

River discharges

The Noyo River drains an area of approximately 106 square miles. River discharge data obtained from water discharge records during the period 1952-1981 were available from a water-stage recorder gage located 3.5 miles east of the river mouth. Based on these data, the following river discharges and recurrence intervals were projected by SPN and simulated in the model.

Discharge, *Q* cfs	Recurrence Interval, years
7,000	2
20,000	10
27,000	25
33,000	50
41,000	100

Analysis of Model Data

Relative merits of the improvement plan were evaluated by:

a. Comparison of wave heights at selected locations in the model.

b. Comparison of sediment tracer movement and subsequent deposits.

c. Visual observations and wave-pattern photographs.

In the wave-height data analysis, the average height of the highest one-third of the waves, significant wave height, recorded at each gage location was computed. All wave heights were then adjusted to compensate for excessive model wave-height attenuation due to viscous bottom friction by application of Keulegan's equation.[1] From this equation, reduction of wave heights in the model (relative to the prototype) can be calculated as a function of water depth, width of wave front, wave period, water viscosity, and distance of wave travel.

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[1] G. H. Keulegan. (1950). "The gradual dampening of a progressive oscillatory wave with distance in a prismatic rectangular channel," unpublished data, National Bureau of Standards, Washington, DC, prepared at request of Director, WES, Vicksburg, MS, by letter of 2 May 1950.

4 Tests and Results

Tests

Existing conditions

Prior to testing of the improvement plan, tests were conducted for existing conditions (Plate 1) to establish a base from which to evaluate the effectiveness of the improvement plan. Short period wave-height data were obtained in the cove and harbor entrance and along the center lines of the proposed breakwaters (for design wave information) for the selected test wave conditions. Wave-pattern photographs were secured for representative test waves from the five test directions, and riverine sediment tracer patterns were obtained for various river discharges as well as wave-induced sediment tracer movement and subsequent deposits. Long-period wave test data obtained for existing conditions in previous studies (Bottin, Acuff, and Markle 1988) were used for comparison of test results with the proposed plan.

Improvement plan

The improvement plan (Plate 2) consisted of a 400-ft-long offshore breakwater constructed in the cove approximately 2,000 ft from the Noyo River and Harbor jettied entrance. The breakwater had a crest el of +20 ft with side slopes of 1V:1.33H along the trunk and 1V:1.67H at the heads. As stated earlier, the structure was constructed of stone in the model, but represented an accropode armored structure (based on transmission characteristics obtained during two-dimensional model testing). Short-period wave-height tests, riverine and wave-induced sediment tracer patterns, and long-period wave tests, as well as wave-pattern photographs, were secured for the proposed improvement plan.

Short-period wave-height tests

Wave-height tests for existing conditions and the improvement plan were conducted for the selected test waves and directions listed in Chapter 3. Wave gage locations are shown in Plates 1 and 2.

Sediment tracer tests

Riverine sediment tracer tests were conducted for existing conditions and the offshore breakwater plan using river discharges ranging from 7,000 to 41,000 cfs. Tracer material was introduced into the model in the lower reaches of the river to represent bed-load sediment. These tests were also conducted with various wave conditions from west and west-northwest superimposed for existing conditions and the offshore breakwater plan. Wave-induced sediment tracer tests were also conducted for waves from northwest and southwest. Tracer material was introduced north and south of the cove to represent sediment along those shorelines.

Long-period wave tests

Long-period (60 to 200 sec) wave tests were conducted for the breakwater improvement plan and compared with tests conducted previously (Bottin, Acuff, and Markle 1988) for existing conditions. These tests were conducted using test waves from the west. Two types of tests involved with investigating long-period waves are as follows:

a. Frequency response tests involved the placement of wave sensors at strategic locations throughout the harbor to measure the amplitude of the oscillations. By plotting the ratio of the measured wave height at each gage to the incident wave height (response factor) versus the wave periods tested, frequency response curves showing resonant peaks were obtained.

b. Surface-float tests were conducted using small white squares of styrofoam confetti to determine oscillation patterns. The confetti was spread over the surface of the channel and basins, and subsequent movement by each wave period was observed. Through visual observations, the oscillation patterns and location of nodes and antinodes were determined.

Wave patterns

Wave patterns (black and white photographs and color slides) were obtained for existing conditions and the offshore breakwater plan for representative test waves from the five selected test directions.

Results

In evaluating test results, the merits of the improvement plan were based on an analysis of measured wave heights in the harbor entrance. Model wave heights (significant wave heights or $H_{1/3}$) were tabulated to show measured values at selected locations. Wave heights in the jettied entrance also were plotted graphically versus various wave conditions to show the impact of the offshore breakwater. The impact of the improvement plan on long-period wave conditions was determined through frequency response curves (response factor versus wave period), and the general movement of riverine sediment tracer material and subsequent deposits was shown in photographs. Arrows were superimposed onto these photographs to depict sediment movement patterns.

Short-period wave-height tests

Results of short-period wave-height tests conducted for existing conditions are presented in Tables 4-13 for test waves from the five directions with the 0.0- and +7.0-ft swl's. For the 0.0-ft swl, maximum wave heights[1] were 12.2 ft in the entrance (Gage 1) for 17-sec, 28-ft test waves from west; 27.1 ft at the proposed breakwater location (Gage 9) for 17-sec, 22-ft test waves from northwest; and 28.7 ft at the alternate breakwater location (Gage 5) from 17-sec, 20-ft test waves from west. For the +7.0-ft swl, maximum wave heights were 15.2 ft in the entrance for 13-sec, 22-ft test waves from west-northwest; 30.9 ft at the proposed breakwater location for 17-sec, 28-ft test waves from west-northwest; and 30.3 ft at the alternate breakwater location for 13-sec, 20-ft test waves from northwest. For waves of 14 ft or less (operational waves), maximum wave heights in the jettied entrance were 9.7 ft for 15-sec, 14-ft test waves from west-northwest and 17-sec, 10-ft test waves from west with the 0.0-ft swl. For the +7.0-ft swl, maximum wave heights in the entrance were 13.7 ft for 17-sec, 14-ft test waves from west-southwest and 13-sec, 14-ft test waves from southwest for waves of 14 ft or less. Typical wave patterns obtained for existing conditions are shown in Photos 1-20.

Short-period wave-height test results conducted with the offshore breakwater plan installed are shown in Tables 14-23 for test waves from the five directions with the 0.0- and +7.0-ft swl's. For the 0.0-ft swl, maximum wave heights were 11.3 ft in the entrance for 19-sec, 22-ft test waves from west-northwest; and with the +7.0-ft swl, 14.6 ft in the entrance for 15-sec, 30-ft test waves from west-northwest. For operational wave conditions (14-ft waves or less) maximum wave heights were 9.0 ft in the entrance for 15-sec, 14-ft test waves from west-northwest with the 0.0-ft swl; and 9.3 ft in the entrance for 11-sec, 14-ft test waves from west

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[1] Refers to maximum significant wave heights throughout report.

with the +7.0-ft swl. Typical wave patterns for the offshore breakwater plan are shown in Photos 21-40.

Discussion of short-period wave tests

Results of wave-height tests for existing conditions indicated rough and turbulent wave conditions in the cove and jettied entrance to Noyo River. Considering all test conditions, wave heights ranged from 22.0 to 30.9 ft at the proposed breakwater location in the cove and from 12.2 to 15.2 ft in the entrance, depending on incident wave direction. For operational wave conditions (14-ft waves or less), wave heights ranged from 8.5 to 13.7 ft in the entrance from the various incident wave directions.

Wave-height tests with the offshore breakwater plan installed revealed 8.7- to 14.6-ft waves in the entrance for the various incident wave directions, considering all test conditions. For operational wave conditions, maximum wave heights ranged 6.3 to 9.3 ft in the entrance, depending on incident wave direction.

Comparisons of maximum wave heights in the Noyo River jettied entrance for existing conditions and the offshore breakwater plan are shown in Plates 3-12. Wave-height values for test waves from northwest with the 0.0- and +7.0-ft swl's (Plates 3 and 4) and from west-northwest with the 0.0-ft swl (Plate 5) were similar for both existing conditions and the breakwater plan. Most operational waves that exceeded the 6-ft wave-height criterion for existing conditions also exceeded it for the breakwater plan. Test results for waves from west-northwest with the +7.0-ft swl (Plate 6) revealed that 12- to 14-ft incident waves were within the established 6.0-ft criterion for the offshore breakwater plan and exceeded it for existing conditions. Results for test waves from west (Plates 7 and 8) indicated that the breakwater plan was slightly better than existing conditions; however, the wave-height criterion was still exceeded for several operational test wave conditions. In general, test waves from west-southwest (Plates 9 and 10) and southwest (Plates 11 and 12) resulted in significantly reduced wave heights in the entrance for the offshore breakwater plan versus existing conditions. The wave-height criterion will be exceeded by some operational wave conditions from west-southwest with the +7.0-ft swl (Plate 10).

An analysis of maximum wave heights obtained in the jettied entrance for existing conditions and the offshore breakwater plan versus the number of occurrences of 14-ft waves or less from Table 3 is shown in the following tabulation:

Occurrences of Operational Waves from Hindcast Data			
		Occurrences 6-ft Wave Height Criterion in Entrance is Exceeded	
Direction	Total Occurrences	Existing Conditions	Offshore Breakwater Plan
Northwest	13,295	1,412	1,607
West-northwest	16,416	5,050	2,729
West	4,536	3,001	1,952
West-southwest	991	440	72
Southwest	347	230	0
Total	35,585	10,133	6,360

Based on the hindcast data in Table 3, total occurrences with incident waves of 14 ft or less were 35,585 for all five test directions. Occurrences in which the 6.0-ft wave-height criterion in the jettied entrance is exceeded were 10,133 for existing conditions and 6,360 for the offshore breakwater plan (based on wave heights obtained in the model). These data indicate that for operational waves (14 ft or less) approaching from northwest counterclockwise to southwest, the criterion is currently exceeded 28.5 percent of the time, and with the breakwater plan installed the criterion will be exceeded about 18 percent of the time. The breakwater plan will result in the entrance criterion being achieved 37 percent more of the time for operational wave conditions than it currently is for existing conditions. This is equivalent to about 23.5 days per year on the average. In summary, the offshore breakwater plan will increase the amount of time wave heights in the harbor entrance meet the 6.0-ft criterion; however, the criterion will not be met for all operational wave conditions.

For all operational wave conditions (14 ft or less) generated in the model study, the values of the maximum wave heights in the entrance were averaged for existing conditions and the offshore breakwater plan. Average values per direction are shown in the following tabulation:

	Average Values of Operational Waves	
Direction	Existing Conditions	Offshore Breakwater Plan
Northwest	4.4	4.6
West-northwest	5.1	4.5
West	6.3	5.0
West-southwest	7.7	4.5
Southwest	7.4	3.7
Average	6.2	4.5

The average values of wave heights in the entrance for all operational wave conditions and all five directions are 6.2 ft for existing conditions and 4.5 ft for the offshore breakwater plan. These data indicate that the magnitude of the average wave height in the jettied entrance is decreased by about 27 percent as a result of the offshore breakwater.

Sediment tracer tests

Riverine sediment tracer patterns for existing conditions are shown in Photos 41-45 for river discharges ranging from 7,000 to 41,000 cfs with no waves. The 2-year discharge (7,000 cfs) barely moved the tracer material, but each successively larger flow resulted in tracer deposits further seaward in Noyo Cove.

Sediment tracer patterns from the river with the offshore breakwater installed are shown in Photos 46-50 for river discharges ranging from 7,000 to 41,000 cfs with no waves. Again, the 7,000-cfs discharge hardly moved the tracer material out of the river mouth, but successively larger discharges moved the material further seaward in the cove. The offshore breakwater prevented the maximum (41,000 cfs) discharge from moving the tracer material as far seaward as it moved under existing conditions.

Riverine sediment tracer patterns for existing conditions are shown in Photos 51-66 for river discharges ranging from 20,000 to 41,000 cfs with 13-sec, 14-ft and 15-sec, 20-ft waves from west-northwest and west. For waves from west-northwest (Photos 51-58), sediment tracer migrated seaward from the river entrance. Instead of moving directly down the axis of the channel, the material moved slightly northerly as it entered the cove. Successively larger discharges resulted in the material moving further seaward and into a counterclockwise eddy in the cove. For 13-sec, 14-ft test waves from west (Photos 59-62), riverine sediment patterns were similar to the west-northwest patterns. After clearing the jetties, material moved northerly, and larger discharges resulted in seaward migration of the material in a counterclockwise eddy. For 15-sec, 20-ft test waves (Photos 63-66), however, material entering the cove moved slightly south of the jettied entrance and then into a clockwise eddy. The material did not move as far seaward in the cove for the larger discharges as it had done in previous tests.

Sediment tracer patterns from the river with the offshore breakwater plan installed are presented in Photos 67-82 for 20,000- to 41,000-cfs river discharges with 13-sec, 14-ft and 15-sec, 20-ft test waves from west-northwest and west. For test waves from west-northwest (Photos 67-74), riverine sediment moved into a counterclockwise eddy immediately outside the jettied entrance for the 20,000-cfs discharge. Successively larger discharges resulted in the material moving in a slightly northerly path toward the seaward head of the offshore breakwater. Larger discharges resulted in more seaward deposits. For 13-sec, 14-ft test waves from west (Photos 75-78), material migrated from the entrance toward the head of

the offshore structure with the larger discharges moving the sediment further seaward. For 15-sec, 14-ft test waves from west (Photos 79-82), material moved into a counterclockwise eddy once in the cove, and larger discharges resulted in sediment movement and subsequent deposits more northerly in the vicinity of the seaward head of the offshore breakwater.

Wave-induced sediment tracer patterns and subsequent deposits for existing conditions are shown in Photos 83-86 for test waves from northwest and southwest. For waves from northwest, material generally moved into the cove and deposited in a clockwise eddy in the northern portion of the cove. Test waves from southwest resulted in material migrating into the cove and generally depositing in a counterclockwise eddy. Northwest waves moved the material further toward the center of the cove than did wave conditions from southwest.

Results of wave-induced sediment tracer tests for the offshore breakwater plan are presented in Photos 87-90 for test waves from northwest and southwest. For test waves from northwest, tracer material moved into the cove and deposited in a clockwise eddy in the northern portion similar to existing conditions. For waves from southwest, some sediment material migrated into the cove between the breakwater and the shoreline, and some deposited seaward of the breakwater in a counterclockwise eddy.

Discussion of sediment tracer tests

A comparison of riverine sediment tracer patterns for existing conditions and the offshore breakwater plan with no waves indicates that the patterns are similar, with the exception of the 100-year (41,000 cfs) discharge. The breakwater prevented the material from moving as far seaward in the cove as it did under existing conditions.

A comparison of riverine sediment tracer patterns for the offshore breakwater plan with wave conditions from west-northwest and west indicates that the breakwater slightly changes the paths of migration and subsequent deposits for some river discharges and does not for others. For 13-sec, 14-ft test waves from west-northwest, tracer material moved further seaward into the cove without the breakwater in place, in particular for the 20,000- and 27,000-cfs discharges. The higher discharges (33,000 and 41,000 cfs) resulted in similar patterns for existing conditions and the breakwater plan for these wave conditions. For 13-sec, 14-ft waves from west, sediment moved straight out of the river into the cove with the breakwater installed for the various discharges. Without the structure in place, material migrated more northerly after entering the cove. Successively larger discharges also resulted in material moving in a slightly more northerly path than it did with the structure installed. For 15-sec, 20-ft test waves from west-northwest, sediment tracer patterns in the cove were similar for the various discharges both with and without the offshore structure. These wave conditions from west resulted in material migrating slightly further seaward for the 27,000- to 41,000-cfs discharges with the

breakwater installed. In general, considering all test conditions, riverine sediment deposited in an area in the cove between the existing Noyo River jetties and the proposed structure location, whether the breakwater was installed or not.

A comparison of wave-induced sediment tracer tests for existing conditions and the offshore breakwater plan reveals that the breakwater had little effect on tracer patterns and subsequent deposits for test waves from northwest. For test waves from southwest, however, the breakwater resulted in a slight shift of the tracer path as it entered the cove. The breakwater prevented the material from penetrating as deeply shoreward into the cove as it did under existing conditions.

Long-period wave tests

Long-period (60 to 200 sec) wave tests were conducted during previous studies (Bottin, Acuff, and Markle 1988) for existing conditions using waves from the west direction with a +7.0-ft swl. The gage arrangement for these tests is shown in Plate 13. To ensure accurate determination of incident wave height, the first 10 gages were placed in an array at the river entrance to measure nodes and antinodes of possible standing waves. The incident wave height was then calculated from the following relationship:

$$H_i = \frac{H_a + H_n}{2}$$

where

H_i = incident wave height

H_a = wave height at antinode

H_n = wave height at node

Test results obtained with the gage array were used to determine incident wave heights in the entrance and corresponding wave-machine stroke settings. During the tests, squares of styrofoam confetti were spread over the water surface and observed over the 60- to 200-sec period range. Areas of maximum horizontal movement (nodes) and minimum horizontal movement (antinodes) were identified through this series of visual observations. Wave gages were placed in antinodal areas. Measured wave heights at a particular gage location were divided by the incident wave height for that period to obtain the response factor or $R = H/H_i$. Frequency response (response factor versus wave period) curves were subsequently plotted for Gages 11-20.

Frequency response curves for existing conditions are shown in Plates 14-23. These test results indicate that resonant peaks (with amplification factors in excess of 1.0) will occur at various stations in Noyo

River (Gages 11-15 and 19) for wave periods of 60, 90, 95, 110, 115, 130, 150, 155, 165, and 185 sec. Resonant peaks (with amplification factors in excess of 1.0) will occur in Noyo Harbor (Gages 16-18) for wave periods of 75, 95, 102.5, 115, and 155 sec. The maximum peak in Dolphin Marina (Gage 20) occurred for a 110-sec wave period with an amplification factor of 0.95.

Frequency response curves obtained for the offshore breakwater plan also are shown in Plates 14-23. Results indicate that resonant peaks (with amplification factors in excess of 1.0) will occur at various stations in Noyo River for wave periods of 85, 90, 95, 100, 105, 115, 120, 125, 130, 135, 140, 145, 150, 155, 160, 165, 170, 175, 180, 185, 190, 195, and 200 sec. Resonant peaks with amplification factors greater than 1.0 will occur in Noyo Harbor for wave periods of 90, 95, 100, 105, 110, 115, 120, 140, 145, 150, 155, and 160 sec. The maximum peak in Dolphin Marina occurred for a 140-sec wave period and had an amplification factor of 0.55.

Discussion of long-period wave tests

A comparison of long-period wave test results for existing conditions and the offshore breakwater plan indicates similar frequency response conditions in Noyo Harbor. Maximum response factors of 1.92 and 1.97 occurred for existing conditions and the breakwater plan, respectively, in the southern corner of the harbor (Gage 16). In some cases, response factors were slightly larger for existing conditions for some wave periods, and in other instances, they were slightly larger for the offshore breakwater plan for some wave periods. In general, it appears that construction of the offshore breakwater will not have any negative impacts on surge conditions in Noyo Harbor.

Maximum response factors of 0.95 and 0.55 occurred in Dolphin Marina for existing conditions and the offshore breakwater plan, respectively. Frequency response over the entire period range was generally slightly lower for the offshore breakwater plan than for existing conditions.

A comparison of frequency response in Noyo River indicated maximum values of 2.9 and 2.33, respectively, for existing conditions and the offshore breakwater plan. In the lower reaches of the river, however, for some period ranges the offshore breakwater plan resulted in slightly larger frequency response values with wider peaks than existing conditions did. Since surging has not been a problem in this area in the prototype, it is not expected to become a problem with the offshore breakwater installed.

5 Conclusions

Based on the results of the hydraulic model investigation reported herein, it is concluded that:

a. Existing conditions are characterized by rough and turbulent wave conditions in the Noyo River entrance. Maximum wave heights ranged from 8.5 to 13.7 ft in the entrance for operational conditions (incident waves with heights of 14 ft or less) and from 12.2 to 15.2 ft for extreme conditions (waves up to 32 ft in height), depending on incident wave direction.

b. The offshore breakwater plan will result in maximum wave heights ranging from 6.3 to 9.3 ft in the entrance for operational wave conditions and 8.7 to 14.6 ft for extreme conditions, depending on incident wave direction.

c. The offshore breakwater plan will not meet the 6.0-ft wave-height criterion in the entrance for all incident waves of 14 ft or less (operational conditions). Based on hindcast data, however, the breakwater plan will result in the criterion being achieved 37 percent more of the time than it currently is for existing conditions when operational waves are present. This is equivalent to an average of 23.5 days per year. The magnitude of the average wave height in the jettied entrance will be decreased by about 27 percent as a result of the offshore breakwater for operational waves.

d. With no waves present, the offshore breakwater resulted in riverine sediment patterns similar to those obtained for existing conditions except for the 100-year (41,000 cfs) discharge. For this condition, the breakwater prevented material from moving as far seaward in the cove as it did under existing conditions.

e. With waves present from west-northwest and west, the offshore breakwater slightly changes the paths of migration and subsequent deposits for some river discharges and does not for others. In general, considering all test conditions, riverine sediment will deposit in an area in the cove between the existing jettied entrance

and the proposed structure location, both with and without the breakwater installed.

f. The offshore breakwater will not interfere with the migration of wave-induced sediment into the cove for waves from northwest; however, for waves from southwest, the breakwater will prevent some sediment from penetrating as deeply shoreward in the cove as it did under existing conditions.

g. The offshore breakwater plan will have no adverse impact on surge conditions due to long-period wave energy in Noyo Harbor, Dolphin Marina, and the lower reaches of the river.

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Table 1
Summary of Refraction and Shoaling Analysis for Noyo Harbor

Wave Period, sec	Shallow-Water Azimuth, deg	Refraction[1] Coefficient	Shoaling[2] Coefficient	Wave-Height Adjustment Factor
Northwest, 315 deg				
7	312.2	0.981	0.956	0.938
9	307.3	0.950	0.917	0.871
11	302.8	0.926	0.917	0.849
13	299.3	0.912	0.938	0.855
15	296.2	0.897	0.971	0.871
17	293.1	0.889	1.009	0.897
19	290.9	0.885	1.044	0.924
West-Northwest, 292.5 deg				
7	292.5	0.998	0.956	0.954
9	291.3	0.992	0.917	0.910
11	289.8	0.993	0.917	0.911
13	288.4	0.996	0.938	0.934
15	287.1	1.006	0.971	0.977
17	285.7	1.003	1.009	1.012
19	284.5	1.010	1.044	1.054
West, 270 deg				
7	270.0	1.000	0.956	0.956
9	270.2	0.995	0.917	0.912
11	270.0	0.992	0.917	0.910
13	270.1	0.981	0.938	0.920
15	270.4	0.973	0.971	0.945
17	270.5	0.972	1.009	0.981
19	270.6	0.975	1.044	1.018
West-Southwest, 247.5 deg				
7	247.5	0.999	0.956	0.955
9	249.4	0.990	0.917	0.908
11	251.8	0.988	0.917	0.906
13	254.1	0.989	0.938	0.928
15	255.9	0.996	0.971	0.967
17	257.7	1.002	1.009	1.001
19	259.1	1.011	1.044	1.055

(Continued)

[1] At approximate locations of wave generator in model.
[2] At 81-ft depth (75-ft pit elevation with 6-ft storm tide conditions superimposed).

Table 1 (Concluded)

Wave Period, sec	Shallow-Water Aximuth, deg	Refraction Coefficient	Shoaling Coefficient	Wave-Height Adjustment Factor
Southwest, 225 deg				
7	225.8	0.988	0.956	0.945
9	229.5	0.953	0.917	0.874
11	234.2	0.929	0.917	0.852
13	238.4	0.919	0.938	0.862
15	242.4	0.903	0.971	0.877
17	245.7	0.891	1.009	0.899
19	248.4	0.882	1.044	0.921

Table 2
Estimated Magnitude of Deepwater Waves (Sea and Swell) Approaching Noyo Harbor from the Directions Indicated

Wave Height, ft	Occurrences[1] per Wave Period, sec							
	4.4-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	>18.2	Total
Northwest								
0-3.1	19	6						25
3.1-6.4	1,052	775	366	17		6		2,216
6.4-9.7	3,368	1,038	2,386	158	23	1		6,974
9.7-13.0	1,465	223	1,025	819	145	11	2	3,690
13.0-16.3	135	255	43	347	184	12		976
16.3-19.6	1	68	11	20	82	9		191
19.6-22.9		10	12	1	11	13		47
22.9-26.2			2					2
Total	6,040	2,375	3,845	1,362	445	52	2	14,121
West-Northwest								
0-3.1	5	29						34
3.1-6.4	206	880	925	60	8	5		2,084
6.4-9.7	302	656	4,446	1,578	182	16	9	7,189
9.7-13.0	243	79	1,870	3,649	1,190	78		7,109
13.0-16.3	18	138	347	1,746	1,629	172	1	4,051
16.3-19.6		46	65	301	944	289	1	1,646
19.6-22.9			14	26	157	202		399
22.9-26.2			1		45	72		118
26.2-29.5					2	8		10
29.5-32.8						9		9
>32.8						4		4
Total	774	1,828	7,668	7,360	4,157	855	11	22,653

[1] Occurrences compiled for period 1956-1975.

(Sheet 1 of 3)

Table 2 (Continued)

Wave Height, ft	Occurrences per Wave Period, sec							
	4.4-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	>18.2	Total
West								
0-3.1								
3.1-6.4	51	135	157	22				365
6.4-9.7	52	218	927	358	34	5		1,594
9.7-13.0	80	63	803	1,256	356	19		2,577
13.0-16.3	20	55	289	1,111	834	46		2,355
16.3-19.6	1	30	70	286	704	48		1,139
19.6-22.9		1	14	65	258	92		430
22.9-26.2			2	3	52	65		122
26.2-29.5			2	4	2	4		12
29.5-32.8			3		2	10		15
Total	204	502	2,267	3,105	2,242	289		8,609
West-Southwest								
0-3.1								
3.1-6.4	14	34	1					49
6.4-9.7	64	113	127	9	2			315
9.7-13.0	97	65	297	141	25	2		627
13.0-16.3	33	89	255	285	88	3		753
16.3-19.6	2	72	104	182	148	5		513
19.6-22.9		8	63	79	124	8		282
22.9-26.2			13	26	31	12		82
26.2-29.5			5	4	10			19
29.5-32.8			1	4	9			14
>32.8				1				1
Total	210	381	866	731	437	30		2,655

(Sheet 2 of 3)

Table 2 (Concluded)

Wave Height, ft	Occurrences per Wave Period, sec							
	4.4-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	>18.2	Total
				Southwest				
0-3.1								
3.1-6.4	1		3					4
6.4-9.7	47	11	9	1				68
9.7-13.0	92	40	71	32	1			236
13.0-16.3	57	112	39	44	17			269
16.3-19.6	4	105	77	48	18			252
19.6-22.9		19	117	41	33	2		212
22.9-26.2			47	11	11			69
26.2-29.5			9	3	5			17
29.5-32.8			2	6	3			11
>32.8			1	6	1			8
Total	201	287	375	192	89	2		1,146

(Sheet 3 of 3)

Table 3
Estimated Magnitude of Shallow-Water Waves (Sea and Swell) Approaching Noyo Harbor from the Directions Indicated

Wave Height, ft	Occurrences[1] per Wave Period, sec							
	4.4-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	>18.2	Total
				Northwest				
1-4	19	6						25
4-6		775	366	17		6		1,164
6-8	1,052							1,052
8-10	3,368	1,038	2,386	158	23	1		6,974
10-12		223	1,025	819	145	11	2	2,225
12-14	1,465		43	347				1,855
14-16	135	255			184	12		586
16-18		68	11	20	82	9		190
18-20	1	10	12	1	11			35
20-22						13		13
22-24			2					2
Total	6,040	2,375	3,845	1,362	445	52	2	14,121

[1] Occurrences compiled for period 1956-1976.

(Sheet 1 of 5)

Table 3 (Continued)

Wave Height, ft	Occurrences per Wave Period, sec							
	4.4-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	>18.2	Total
West-Northwest								
1-4	5	29						34
4-6		880	925	60				1,865
6-8	206				8	5		219
8-10	302	656	4,446	1,578	182	16		7,180
10-12		79	1,870				9	1,958
12-14	243			3,649	1,190	78		5,160
14-16	18	138	347	1,746	1,629			3,878
16-18		46	65			172	1	284
18-20				301	944	289		1,534
20-22			14	26			1	41
22-24			1		157	202		360
24-26					45			45
26-28						72		72
28-30					2	8		10
30-32								0
32-34						9		9
>34						4		4
Total	774	1,828	7,668	7,360	4,157	855	11	22,653

(Sheet 2 of 5)

Table 3 (Continued)

Wave Height, ft	Occurrences per Wave Period, sec							
	4.4-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	>18.2	Total
West								
4-6		135	157	22				314
6-8	51							51
8-10	52	218	927	358	34	5		1,594
10-12		63	803	1,256				2,122
12-14	80				356	19		455
14-16	20	55	289	1,111	834	46		2,355
16-18		30	70					100
18-20	1			286	704	48		1,039
20-22		1	14	65	258			338
22-24			2			92		94
24-26				3	52	65		120
26-28			2		2			4
28-30			3	4	2	4		13
30-32								
32-34						10		10
Total	204	502	2,267	3,105	2,242	289		8,609

(Sheet 3 of 5)

Table 3 (Continued)

Wave Height, ft	Occurrences per Wave Period, sec							
	4.4-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	>18.2	Total
				West-Southwest				
4-6		34	1					35
6-8	14							14
8-10	64	113	127	9	2			315
10-12		65	297					362
12-14	97			141	25	2		265
14-16	33	89	255	285	88			750
16-18		72	104			3		179
18-20	2			182	148	5		337
20-22		8	63	79				150
22-24			13		124	8		145
24-26				26	31			57
26-28			5	4		12		21
28-30			1		10			11
30-32				4	9			13
32-34				1				1
Total	210	381	866	731	437	30		2,655

(Sheet 4 of 5)

Table 3 (Concluded)

Wave Height, ft	Occurrences per Wave Period, sec							
	4.4-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	>18.2	Total
Southwest								
4-6			3					3
6-8	1							1
8-10	47	11	9	1	1			69
10-12		40	71	32				143
12-14	92		39					131
14-16	57	112		44	17			230
16-18		105	77	48				230
18-20	4		117	41	18			180
20-22		19			33	2		54
22-24			47	11	11			69
24-26			9	3	5			17
26-28			2					2
28-30			1	6	3			10
30-32				6	1			7
Total	201	287	375	192	89	2		1,146

(Sheet 5 of 5)

Table 4
Wave Heights for Existing Conditions for Test Waves from Northwest, swl = 0.0 ft

Test Wave		Wave Height, ft											
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12
7	8	2.0	3.0	5.2	4.3	14.0	11.5	13.6	7.7	7.1	12.6	12.8	7.6
	14	4.8	5.1	6.3	11.5	11.7	17.1	17.8	12.8	14.4	10.7	10.9	8.0
	20	5.4	6.9	9.9	9.5	19.6	10.2	11.5	10.0	21.5	12.8	10.6	8.6
9	6	1.2	1.9	2.2	1.6	9.7	9.3	6.6	5.0	5.1	7.0	7.4	7.0
	12	2.9	4.5	6.2	7.4	13.9	13.6	15.2	16.7	12.5	12.4	11.3	11.3
	20	6.8	8.7	12.2	16.3	19.6	13.2	12.6	10.5	21.2	16.6	14.1	11.5
11	6	0.8	1.1	2.5	2.7	5.3	6.0	6.6	4.8	5.1	5.1	6.1	8.8
	14	5.3	5.8	9.9	10.9	17.4	15.3	13.2	11.5	18.3	19.7	13.1	11.9
	24	5.9	7.5	12.8	16.0	17.9	14.9	11.4	15.0	21.7	19.2	12.9	9.8
13	6	1.5	2.3	3.1	5.0	5.8	9.0	8.4	6.5	6.6	5.3	8.2	6.4
	14	5.5	6.7	9.2	12.1	18.6	16.7	12.2	12.7	16.1	13.2	10.7	12.7
	20	9.1	11.8	15.6	15.7	17.8	15.8	14.9	10.4	23.4	17.1	13.0	8.8
15	10	7.8	7.7	9.5	9.2	20.0	16.7	17.9	14.0	19.2	20.7	11.5	10.4
	14	9.3	9.4	13.9	11.6	22.9	14.1	13.9	15.8	24.2	21.7	11.2	10.2
	20	8.3	8.2	11.5	13.2	22.1	14.6	14.9	12.2	22.8	23.0	13.6	10.6
17	6	2.2	2.6	4.1	4.6	9.4	9.2	8.0	6.7	8.5	10.5	8.3	8.5
	12	7.3	6.1	9.0	8.9	22.3	18.9	16.8	14.3	19.8	20.9	13.1	9.9
	22	9.4	11.0	15.5	14.3	26.0	21.8	14.3	10.7	27.1	22.8	15.3	12.5
19	12	7.2	11.3	15.9	13.0	22.9	20.0	16.3	15.8	19.8	20.4	14.3	11.3

Table 5
Wave Heights for Existing Conditions for Test Waves from West-Northwest, swl = 0.0 ft

Test Wave		Wave Height, ft											
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12
7	8	2.4	2.9	5.2	5.9	6.7	3.6	7.5	5.4	8.2	4.0	6.1	9.7
	16	6.9	11.4	17.7	20.8	17.7	11.1	13.9	12.0	20.4	12.3	9.2	10.3
9	6	0.9	1.6	2.3	4.0	9.7	6.4	4.4	4.3	8.4	4.8	4.5	4.5
	10	2.9	4.0	5.2	6.9	17.4	14.4	10.7	6.7	17.6	9.0	10.6	11.6
	18	7.8	13.8	20.1	16.4	15.4	15.4	13.0	13.5	18.2	12.1	12.1	12.2
11	6	1.6	2.1	2.9	4.2	10.6	7.1	4.3	7.3	8.8	8.7	6.4	4.6
	14	6.8	9.3	13.2	12.1	19.1	15.8	15.9	16.2	20.4	14.1	12.8	10.4
	24	7.8	11.7	16.0	16.6	15.8	12.0	16.3	13.7	20.5	14.2	10.9	12.6
13	6	2.5	3.1	4.2	4.1	12.7	9.9	8.1	7.9	10.5	9.1	9.5	8.2
	14	5.7	7.8	12.4	14.4	17.4	15.4	14.8	15.3	16.3	16.4	11.3	14.4
	22	8.7	16.3	22.0	22.9	16.2	14.4	16.2	14.3	16.0	15.0	11.3	12.2
15	10	8.5	10.5	14.9	10.7	19.9	17.9	18.0	15.7	13.3	19.4	12.4	12.0
	14	9.7	14.1	21.1	16.7	17.4	15.5	16.6	14.9	21.0	15.5	10.3	13.4
	20	10.0	13.5	16.9	19.6	19.5	15.4	15.5	13.6	22.9	15.0	14.5	14.3
	30	9.8	14.1	19.8	22.2	22.9	16.8	16.7	11.5	25.6	20.5	13.9	10.4
17	10	5.8	5.6	8.2	6.6	17.3	20.1	12.6	11.5	16.1	14.2	13.3	11.2
	20	10.5	13.6	17.9	19.6	19.8	19.4	15.4	15.5	21.7	22.3	18.9	13.4
	28	10.4	11.8	17.8	20.5	19.7	21.5	16.4	13.8	24.6	23.5	17.9	11.3
19	12	7.3	8.2	9.9	13.1	20.4	16.5	12.7	14.1	19.7	19.0	13.8	8.5
	22	10.1	13.7	15.0	18.0	22.2	18.6	16.6	15.0	20.3	22.6	14.6	14.2

Table 6
Wave Heights for Existing Conditions for Test Waves from West, swl = 0.0 ft

Test Wave		Wave Height, ft											
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12
7	8	3.3	4.4	6.7	5.5	8.6	5.9	7.0	3.0	9.4	5.0	5.0	5.1
	14	7.0	11.7	16.9	16.8	14.6	8.6	12.7	12.5	9.8	10.8	13.6	12.3
	20	5.2	8.1	11.9	14.5	20.4	11.7	14.8	11.5	17.0	11.6	12.4	11.7
9	6	2.0	2.9	3.8	4.1	4.8	3.7	3.1	5.7	7.0	4.2	3.7	4.7
	14	7.3	9.3	13.4	13.6	12.7	14.0	12.9	15.9	10.2	11.5	15.6	16.2
	22	7.3	9.0	13.1	16.8	16.2	15.4	11.2	15.0	16.0	14.7	13.3	14.7
11	6	4.7	5.7	6.8	9.0	8.6	4.3	3.8	4.3	8.0	6.5	4.9	3.7
	14	6.8	15.2	20.0	20.9	20.6	15.2	14.6	15.6	19.7	18.1	15.0	13.9
	18	7.0	8.8	16.0	18.8	20.1	16.5	17.8	18.1	16.6	13.2	14.9	14.0
	30	7.0	8.9	14.3	16.7	19.7	19.7	12.8	15.9	14.7	16.2	17.1	14.2
13	6	2.7	3.4	5.2	7.9	5.9	4.9	4.1	4.3	5.7	6.3	2.6	5.6
	14	9.0	12.2	14.8	17.6	20.3	15.0	17.2	11.8	22.9	16.7	11.5	17.5
	20	8.5	13.8	16.5	19.5	20.2	19.4	18.3	14.6	18.5	18.9	12.9	15.2
	30	9.6	11.5	16.2	20.3	21.8	14.1	16.1	12.3	18.4	18.8	11.5	13.4
15	10	6.3	5.9	11.4	12.8	18.7	15.5	14.3	10.2	17.9	20.8	16.0	14.3
	14	9.5	15.8	16.1	21.7	21.4	16.1	17.4	16.0	19.8	15.5	13.1	13.9
	20	9.3	11.7	16.1	19.3	19.4	20.3	18.3	12.0	20.4	18.1	13.8	11.5
	30	8.9	10.4	12.4	15.3	24.6	17.1	17.3	14.0	22.1	21.2	16.1	15.3
17	10	9.7	8.2	14.1	12.2	20.4	17.3	18.7	16.5	18.2	16.0	15.4	16.6
	20	11.4	13.5	21.3	20.7	28.7	20.4	15.6	13.4	19.1	20.0	17.4	14.7
	28	12.2	12.2	21.7	19.7	25.1	18.6	15.3	15.9	17.3	18.3	14.3	15.8

Table 7
Wave Heights for Existing Conditions for Test Waves from West-Southwest, swl = 0.0 ft

Test Wave		Wave Height, ft											
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12
7	8	4.4	4.8	5.8	5.4	8.0	5.1	8.3	7.8	7.8	6.9	7.1	8.2
	14	4.9	5.7	9.0	13.9	15.9	12.8	13.6	13.2	15.0	13.9	9.0	11.9
	20	6.6	9.4	13.5	15.1	16.6	13.8	13.5	14.2	14.4	14.3	15.3	11.8
9	6	1.4	2.7	3.1	3.3	3.3	3.1	4.9	5.1	2.5	3.6	3.7	9.2
	14	6.3	8.4	8.1	14.5	10.8	17.8	13.7	17.6	13.2	11.4	9.9	13.4
	22	6.6	7.5	10.8	15.0	16.2	18.3	16.5	11.7	14.7	12.7	17.5	13.6
11	10	5.7	8.7	10.4	9.2	8.3	16.1	15.1	14.1	7.3	14.4	11.9	13.7
	14	6.4	11.6	12.0	12.3	18.4	16.0	14.1	17.7	15.8	14.2	10.1	15.3
	20	7.3	9.5	11.8	12.0	21.4	19.0	16.0	13.4	14.5	12.4	12.7	12.4
	30	5.9	7.8	13.7	15.7	17.8	15.7	12.1	13.0	14.3	17.0	11.0	17.1
13	10	9.1	11.3	13.2	10.0	13.4	12.4	16.9	16.8	12.2	13.7	10.8	14.4
	14	7.9	11.4	13.4	14.6	19.4	14.9	21.2	17.9	17.4	18.9	12.8	14.8
	20	8.9	12.0	14.8	16.5	19.7	19.9	15.9	14.3	18.5	18.1	11.6	13.7
	32	7.5	9.9	10.4	16.3	15.0	12.1	13.3	10.8	14.2	13.5	9.7	11.4
15	10	9.0	10.7	13.7	14.2	16.1	16.7	21.0	13.9	18.7	14.7	18.8	15.6
	14	7.9	11.6	14.7	19.1	14.7	22.2	17.5	13.8	19.9	19.5	15.0	11.5
	20	9.0	10.9	12.4	18.2	17.5	14.0	14.5	12.2	14.7	13.8	14.1	9.7
	32	8.3	9.5	10.8	15.8	15.6	16.8	15.2	12.0	16.9	11.6	13.6	12.5
17	14	9.6	11.2	16.7	20.6	17.9	23.0	15.0	14.0	19.5	15.2	13.9	13.2
	20	8.1	10.4	14.9	17.6	18.8	18.3	14.9	12.8	16.3	12.6	12.3	12.4
	28	8.7	11.9	15.9	18.5	19.2	19.0	12.4	10.9	16.5	14.9	11.2	11.0

Table 8
Wave Heights for Existing Conditions for Test Waves from Southwest, swl = 0.0 ft

Test Wave		Wave Height, ft											
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12
7	8	4.7	5.7	6.7	8.3	10.2	6.9	7.8	6.2	8.2	9.3	7.9	8.8
	14	6.4	8.4	9.2	9.4	15.5	12.3	14.5	9.3	15.6	11.5	9.8	8.3
	20	5.3	7.3	11.5	11.1	14.7	10.2	14.0	10.9	12.5	8.9	11.2	10.9
9	10	8.1	7.8	9.9	10.4	11.3	13.2	15.1	11.6	13.0	10.5	12.5	11.7
	14	6.9	8.1	10.5	9.0	17.2	12.5	16.3	15.1	15.3	9.9	18.6	18.5
	22	7.6	8.4	12.8	12.8	17.9	15.5	15.7	14.8	11.9	13.4	16.9	14.4
11	6	3.5	4.0	5.2	5.5	9.1	9.2	4.5	8.6	9.1	8.2	6.3	8.5
	14	6.2	7.7	10.9	13.2	18.8	18.2	14.8	16.4	17.1	13.0	12.9	11.3
	20	7.1	10.0	12.0	13.0	22.1	19.0	13.9	10.4	15.3	16.4	14.5	10.8
	30	5.7	7.9	12.8	13.0	21.3	17.1	17.1	13.3	16.6	17.3	14.7	14.3
13	10	5.9	9.4	11.2	15.7	16.6	14.2	16.8	12.2	17.7	15.3	14.0	12.0
	14	6.1	9.2	10.6	16.2	18.2	8.8	17.9	15.2	18.7	12.7	12.8	10.1
	20	8.0	12.1	16.0	16.2	19.9	16.7	20.0	15.2	18.9	17.4	16.8	17.1
	32	7.1	10.0	12.7	18.3	19.8	19.0	18.5	17.3	16.7	17.4	13.2	17.4
15	10	8.3	12.5	12.4	12.7	19.4	18.1	17.0	16.3	17.7	19.4	12.7	15.3
	14	7.6	11.0	14.3	14.8	19.6	20.5	20.1	12.4	17.4	19.5	18.3	14.8
	20	8.7	11.0	13.0	20.2	19.8	18.7	19.5	12.1	18.2	16.4	18.1	13.1
	32	9.3	10.8	13.1	16.3	16.8	19.5	18.7	12.8	15.9	15.9	15.3	15.3
17	22	9.5	9.0	14.3	19.1	19.3	20.5	18.1	16.2	17.8	15.4	16.8	17.9

Table 9
Wave Heights for Existing Conditions for Test Waves from Northwest, swl = +7.0 ft

Test Wave		Wave Height, ft											
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12
7	8	2.0	2.8	4.3	7.3	5.4	7.5	7.2	5.9	4.6	3.6	6.1	7.5
	14	7.1	8.8	9.1	12.6	12.9	12.4	16.0	15.2	12.2	13.3	11.9	10.0
	20	5.8	8.9	12.0	12.5	26.7	13.8	13.2	12.9	20.4	20.1	16.0	10.9
9	6	1.6	2.8	3.2	4.2	4.6	8.0	6.4	4.7	3.4	4.7	6.4	10.3
	12	2.6	5.6	5.0	8.1	6.4	12.3	11.2	10.3	6.8	10.0	10.7	13.8
	20	6.0	9.6	12.6	16.1	22.1	22.8	18.5	15.4	24.5	18.0	18.6	16.8
11	6	1.4	1.9	3.1	3.6	4.1	6.6	4.8	5.4	4.5	0.8	5.6	7.6
	14	4.9	6.0	8.3	12.6	16.1	19.9	13.4	14.8	18.1	13.4	17.4	11.4
	24	8.0	10.7	12.0	17.0	25.2	18.7	16.0	20.4	26.1	20.8	14.4	15.2
13	6	2.5	3.2	5.0	6.4	8.7	8.8	12.7	7.4	8.7	9.5	10.3	10.4
	14	7.3	7.8	11.0	11.4	26.1	18.3	19.9	19.3	21.7	24.1	15.5	17.3
	20	11.6	11.3	15.9	16.3	30.3	19.7	19.7	13.9	28.2	26.1	13.0	14.9
15	10	3.6	4.7	5.4	6.6	11.6	9.6	8.5	10.2	12.2	8.3	8.7	11.5
	14	5.8	5.3	7.4	7.8	16.4	16.1	12.9	12.4	15.4	11.9	11.0	14.5
	20	8.8	10.1	12.3	13.2	23.0	18.2	16.5	18.9	26.4	16.5	17.6	16.7
17	6	4.6	4.1	5.8	6.0	7.1	9.6	9.8	6.6	9.7	7.1	9.4	10.0
	12	8.5	6.0	9.8	9.9	10.1	12.3	12.4	11.4	14.5	10.1	12.9	10.4
	22	12.2	16.9	19.9	21.5	28.5	23.1	19.0	17.7	28.5	17.7	18.1	16.5
19	12	3.8	5.7	6.5	9.6	12.6	14.6	13.3	14.2	12.9	14.6	19.7	12.8

Table 10
Wave Heights for Existing Conditions for Test Waves from West-Northwest, swl = +7.0 ft

Test Wave		Wave Height, ft											
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12
7	8	3.6	3.2	5.7	7.6	10.2	7.2	7.9	5.5	8.3	8.0	11.8	4.2
	16	12.1	13.8	15.3	22.8	15.5	17.5	12.3	16.8	18.8	13.6	15.9	12.2
9	6	2.0	2.7	3.3	4.2	7.3	6.7	3.8	5.3	6.4	5.6	6.0	7.1
	10	2.0	4.0	4.2	6.7	12.1	10.1	5.4	8.2	11.1	11.8	8.6	9.1
	18	8.4	13.6	20.5	21.0	20.0	17.2	17.2	19.7	17.9	17.9	15.7	15.1
11	6	2.5	3.0	3.0	5.0	10.9	8.4	3.9	5.7	9.9	7.3	7.8	8.0
	14	8.0	10.6	11.5	12.7	24.1	19.7	15.6	17.4	20.6	20.0	15.8	14.3
	24	12.8	16.4	19.8	19.1	19.1	20.3	17.8	18.7	29.7	16.2	15.6	18.9
13	6	2.8	3.9	5.6	7.1	12.9	11.6	12.1	7.8	10.3	9.5	11.4	10.3
	14	9.8	10.0	16.3	14.4	22.9	21.4	21.3	19.4	20.8	20.7	15.1	18.4
	22	15.2	14.7	16.8	17.8	21.1	19.1	19.8	21.1	22.7	18.4	15.1	18.0
15	10	4.6	4.7	5.3	6.3	12.0	12.4	10.3	7.6	11.7	12.5	13.1	11.0
	14	8.9	8.7	11.6	9.6	16.8	18.7	12.6	10.4	13.8	16.6	17.4	11.4
	20	11.0	11.9	16.1	17.7	26.5	19.6	18.2	20.2	25.5	19.4	16.9	18.8
17	10	6.6	10.1	13.1	13.3	19.5	18.6	16.8	18.3	17.9	18.4	16.6	17.6
	20	11.4	14.5	16.9	20.0	23.6	16.6	17.8	19.7	28.9	22.7	16.7	17.2
	28	13.6	15.4	18.2	24.0	25.4	18.3	17.6	19.1	30.9	19.9	19.3	17.9
19	12	6.5	6.3	8.9	12.4	16.6	18.0	15.4	18.5	17.1	20.3	16.1	18.3
	22	12.8	14.9	16.2	19.5	26.1	20.0	19.0	17.5	27.7	21.3	15.0	16.1

Table 11
Wave Heights for Existing Conditions for Test Waves from West, swl = +7.0 ft

Test Wave		Wave Height, ft											
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12
7	8	4.8	5.8	6.8	9.1	9.0	3.5	6.6	6.8	8.2	6.1	6.8	7.0
	14	8.4	10.9	18.4	18.1	16.3	15.9	17.5	11.3	16.7	17.2	14.6	11.8
	20	8.3	11.9	15.0	21.0	21.8	15.2	20.1	12.0	16.1	17.7	17.0	13.4
9	6	2.1	3.9	3.3	4.3	5.3	2.5	5.7	4.1	6.3	5.6	3.7	4.3
	14	7.1	8.5	10.5	14.2	12.8	11.1	9.9	14.7	16.5	10.6	9.6	16.7
	22	10.4	14.3	19.9	24.1	23.9	19.6	14.3	18.9	20.1	19.9	17.1	17.0
11	6	3.9	4.3	5.4	7.3	6.4	6.0	5.1	5.0	8.9	5.7	4.8	4.6
	14	12.3	16.1	20.8	19.7	18.2	17.2	19.9	18.4	17.8	17.6	18.6	15.2
	18	11.3	12.5	17.5	18.7	20.7	22.1	20.1	14.4	19.4	22.8	17.5	14.2
	30	9.0	11.3	12.7	17.2	19.8	17.5	14.0	17.4	19.3	18.3	15.6	14.7
13	6	6.1	6.7	7.2	8.0	5.3	4.7	6.1	7.0	9.0	5.1	6.8	8.6
	14	10.0	10.0	13.1	12.0	16.9	15.3	19.4	20.9	15.3	17.9	17.0	19.2
	20	10.4	11.4	13.1	15.6	17.5	24.3	18.8	15.4	16.9	23.1	19.5	12.9
	30	12.3	14.5	16.4	20.1	28.6	24.9	20.8	16.6	23.8	23.8	17.3	17.2
15	10	3.3	4.7	3.9	5.6	5.0	6.0	6.9	7.4	5.8	6.8	9.0	9.9
	14	4.3	5.6	6.9	7.7	8.6	13.1	12.4	14.4	10.1	14.1	16.0	13.3
	20	11.3	11.1	17.9	15.2	22.9	20.6	22.0	21.9	19.2	19.6	19.8	18.7
	30	12.8	15.6	21.9	24.5	24.0	21.9	21.2	20.7	21.6	25.2	20.7	15.7
17	10	8.4	9.6	15.1	13.5	23.4	24.2	19.9	22.5	21.8	21.3	18.5	19.5
	20	12.4	13.7	20.4	20.7	28.8	25.3	17.9	18.3	25.3	20.8	18.9	15.7
	28	8.3	11.9	14.2	20.2	26.1	26.9	21.5	18.5	30.2	29.4	15.8	17.2

Table 12
Wave Heights for Existing Conditions for Test Waves from West-Southwest, swl = +7.0 ft

Test Wave		Wave Height, ft											
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12
7	8	3.9	6.7	7.8	5.2	F7.3	8.0	6.5	8.0	6.3	8.0	7.8	9.1
	14	8.1	11.6	13.7	14.8	17.1	16.5	17.8	12.6	14.1	16.6	15.1	14.8
	20	10.5	11.8	17.4	16.2	22.6	15.7	22.2	13.6	17.9	17.7	20.6	14.4
9	6	1.9	2.8	3.1	3.7	4.9	4.6	7.0	9.5	4.2	2.6	6.8	9.0
	14	3.6	8.0	12.7	9.2	11.6	13.3	16.2	17.1	12.0	10.2	14.3	15.8
	22	7.2	9.3	10.9	17.7	20.3	20.3	15.7	19.9	21.0	15.3	12.9	17.0
11	10	9.2	9.1	9.6	5.6	6.9	14.6	16.9	11.8	8.3	15.5	12.9	17.3
	14	10.0	11.7	12.9	11.3	13.9	21.9	20.2	19.0	15.2	19.5	13.4	20.8
	20	10.8	15.8	16.8	18.5	21.4	19.7	20.7	16.7	17.1	20.8	17.1	16.4
	30	9.3	13.9	14.8	18.1	24.8	17.4	13.6	15.4	17.5	17.9	15.3	13.2
13	10	12.6	11.6	15.2	11.2	15.1	13.2	19.2	18.2	14.7	11.6	16.8	19.5
	14	9.9	10.9	11.5	15.2	21.1	23.1	23.5	19.0	19.6	17.8	19.8	19.1
	20	13.2	12.1	16.5	18.5	28.0	22.0	21.3	20.2	19.7	22.0	20.0	16.0
	32	13.5	13.7	14.5	18.0	17.8	15.6	16.9	13.1	14.9	16.1	16.3	12.8
15	10	10.5	9.1	8.0	7.9	11.2	9.1	12.4	13.0	9.1	11.2	11.8	15.1
	14	13.1	11.9	19.1	17.0	18.5	17.9	16.5	23.0	18.4	19.8	15.6	20.4
	20	13.5	12.2	18.5	16.6	25.3	17.5	22.0	23.3	18.7	18.2	19.7	20.1
	32	11.5	12.3	15.3	20.4	27.6	19.8	19.3	15.8	18.8	18.6	17.1	13.6
17	14	13.7	13.9	19.3	16.8	22.3	16.0	21.4	23.3	20.8	17.7	19.0	20.4
	20	11.6	11.3	15.8	21.8	20.5	24.4	19.6	18.3	18.7	20.9	19.1	17.1
	28	8.7	11.4	17.3	18.9	26.0	19.6	16.8	17.4	18.6	18.0	16.3	13.6

Table 13
Wave Heights for Existing Conditions for Test Waves from Southwest, swl = +7.0 ft

Test Wave		Wave Height, ft											
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12
7	8	3.7	4.7	6.9	6.5	13.0	7.9	9.4	4.8	8.4	7.1	11.3	10.7
	14	7.1	9.0	10.2	15.2	15.2	19.2	13.8	8.4	18.1	17.5	9.2	13.0
	20	7.7	8.9	13.2	16.6	19.8	16.2	13.7	8.7	14.9	17.3	9.5	11.6
9	10	4.5	8.3	9.5	8.9	12.2	10.7	8.1	12.1	12.2	8.2	10.1	11.2
	14	8.1	13.2	12.0	11.9	17.3	16.1	15.5	14.4	14.0	11.5	13.8	14.2
	22	7.6	11.0	10.8	14.4	19.5	15.7	17.3	12.6	14.5	20.0	16.2	8.3
11	6	2.6	2.5	3.8	4.6	6.2	6.5	6.9	6.5	6.6	4.3	5.8	9.0
	14	10.0	12.0	12.7	17.5	18.9	20.2	22.2	16.2	16.5	23.3	19.9	19.6
	20	8.7	13.0	15.4	19.5	22.2	24.2	20.9	13.6	18.7	19.6	19.7	14.1
	30	8.5	12.7	14.5	18.0	18.8	21.6	20.1	13.3	19.9	22.7	18.0	12.4
13	10	12.6	12.0	19.0	10.6	13.7	11.7	17.8	16.8	14.7	13.9	14.1	19.2
	14	13.7	12.3	17.9	16.8	19.1	20.1	21.3	15.9	20.0	21.8	19.2	18.3
	20	10.0	11.8	14.7	19.7	25.6	23.7	22.1	17.1	21.1	21.7	21.3	17.5
	32	9.3	10.8	14.9	21.2	19.6	22.2	22.3	16.4	21.3	19.8	21.6	16.2
15	10	10.3	12.2	14.1	13.1	17.8	19.8	20.2	14.4	17.8	19.7	20.6	14.9
	14	12.4	12.5	17.1	18.7	22.6	22.2	20.2	18.1	19.7	20.9	23.2	18.7
	20	12.1	13.3	16.7	20.2	22.2	24.5	20.2	17.9	21.8	29.4	21.3	17.6
	32	11.9	13.9	14.6	21.1	24.4	23.6	20.4	15.1	21.4	20.6	17.8	13.8
17	22	14.9	19.1	19.2	21.2	25.9	22.9	20.8	18.7	25.0	24.8	21.3	18.4

Table 14
Wave Heights for the Offshore Breakwater Plan for Test Waves from Northwest, swl = 0.0 ft

Test Wave		Wave Height, ft							
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
7	8	1.3	1.8	4.1	4.2	3.7	3.0	0.1	0.1
	14	4.1	3.9	5.0	6.0	5.6	11.7	0.3	0.1
	20	5.6	6.9	8.9	8.6	8.0	11.2	0.2	0.1
9	6	0.6	1.4	1.9	1.8	1.8	2.4	0.1	0.1
	12	4.5	5.1	5.5	6.9	3.5	6.3	0.3	0.1
	20	6.4	8.9	9.2	10.3	10.6	14.1	0.4	0.1
11	6	1.5	1.6	2.3	2.4	1.7	1.9	0.2	0.1
	14	6.3	7.3	8.5	8.1	7.3	9.9	0.3	0.1
	24	7.0	8.1	11.5	9.8	9.2	13.4	0.5	0.1
13	6	1.3	1.6	2.6	3.9	2.6	2.4	0.1	0.1
	14	7.4	8.0	8.1	9.1	7.5	9.3	0.8	0.1
	20	8.4	9.7	11.0	11.0	10.4	12.8	0.5	0.1
15	10	7.3	7.7	8.3	8.3	6.8	11.0	0.7	0.1
	14	8.3	8.7	8.3	10.7	10.2	12.5	0.9	0.1
	20	9.0	9.4	12.4	12.2	8.7	15.3	0.8	0.1
17	6	2.6	3.9	4.1	4.3	4.6	5.3	0.4	0.1
	12	7.5	7.8	9.6	8.6	7.3	10.4	1.0	0.1
	22	8.9	9.5	17.4	13.6	8.2	14.5	0.9	0.1
19	12	7.1	8.0	8.4	9.3	7.2	12.1	0.8	0.1

Table 15
Wave Heights for the Offshore Breakwater Plan for Test Waves from West-Northwest, swl = 0.0 ft

Test Wave		Wave Height, ft							
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
7	8	2.3	2.8	4.8	6.0	2.4	4.8	0.2	0.1
	16	7.1	12.5	14.1	14.6	10.6	7.2	0.4	0.1
9	6	1.5	2.2	2.5	3.3	2.4	2.5	0.1	0.1
	10	4.2	4.2	4.4	5.6	3.6	6.9	0.3	0.1
	18	8.4	11.7	12.7	16.3	11.7	6.1	0.6	0.1
11	6	1.6	2.0	2.7	2.9	1.7	4.1	0.2	0.1
	14	5.6	7.3	12.6	11.4	7.5	6.1	0.7	0.1
	24	8.5	11.7	14.4	16.7	11.3	11.7	0.6	0.1
13	6	2.1	2.1	4.2	4.3	2.0	3.8	0.3	0.1
	14	7.1	12.9	15.9	16.4	13.0	7.9	0.8	0.1
	22	9.5	15.3	18.6	18.6	14.9	9.4	0.7	0.1
15	10	8.3	9.4	10.5	11.5	12.9	8.9	0.9	0.1
	14	9.0	11.5	13.5	14.7	8.1	12.2	0.9	0.1
	20	9.5	13.2	15.3	15.2	10.8	13.4	1.1	0.2
	30	9.3	13.6	16.9	16.3	13.5	13.9	0.5	0.1
17	10	4.0	5.0	6.8	5.9	5.2	6.8	0.5	0.1
	20	10.3	10.5	16.2	15.1	11.1	13.8	1.3	0.1
	28	10.8	11.5	17.7	16.7	11.4	16.2	1.3	0.2
19	12	6.5	6.0	8.8	11.2	9.3	8.2	0.9	0.1
	22	11.3	13.9	14.3	17.9	14.4	12.3	1.3	0.2

Table 16
Wave Heights for the Offshore Breakwater Plan for Test Waves from West, swl = 0.0 ft

Test Wave		Wave Height, ft							
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
7	8	3.6	5.7	6.0	6.9	5.9	2.2	0.2	0.1
	14	6.7	7.6	10.4	13.6	8.9	3.9	0.4	0.1
	20	3.7	5.4	9.3	9.8	8.2	4.2	0.2	0.1
9	6	2.1	3.0	3.7	5.1	3.7	2.5	0.1	0.1
	14	6.5	9.7	12.5	16.1	12.1	4.3	0.5	0.1
	22	5.4	6.7	12.5	13.2	9.1	8.4	0.4	0.1
11	6	2.2	3.2	4.7	4.6	3.5	2.3	0.2	0.1
	14	6.8	7.9	11.4	13.6	10.2	6.0	0.6	0.1
	18	6.4	7.4	8.4	11.3	12.2	7.9	0.6	0.1
	30	5.4	7.8	10.7	14.1	10.4	9.4	0.6	0.1
13	6	3.6	4.9	5.9	8.0	5.7	5.4	0.6	0.1
	14	5.0	7.5	8.1	13.1	10.6	6.5	0.6	0.1
	20	4.6	6.7	10.2	15.7	7.2	7.1	0.6	0.1
	30	6.4	8.4	11.0	15.8	11.2	8.7	0.7	0.1
15	10	5.8	7.7	10.1	12.0	11.5	10.9	0.7	0.1
	14	8.1	8.7	11.4	14.5	12.8	6.7	0.8	0.1
	20	7.6	9.0	12.1	15.3	12.8	8.9	0.9	0.1
	30	7.9	9.4	12.4	12.9	12.6	11.7	0.6	0.2
17	10	5.6	5.6	8.0	10.0	10.8	8.3	0.6	0.1
	20	7.8	8.5	13.7	16.0	10.7	8.4	1.0	0.1
	28	7.3	7.4	11.6	13.6	10.3	9.5	1.1	0.2

Table 17
Wave Heights for the Offshore Breakwater Plan for Test Waves from West-Southwest, swl = 0.0 ft

Test Wave		Wave Height, ft							
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
7	8	2.7	3.6	3.9	5.7	3.3	3.4	0.2	0.1
	14	2.4	3.6	6.3	8.4	5.4	3.4	0.2	0.1
	20	2.4	3.7	5.9	8.5	5.8	3.9	0.2	0.1
9	6	1.7	2.7	3.8	3.6	2.7	2.9	0.1	0.1
	14	4.9	5.0	6.0	7.3	7.4	4.5	0.3	0.1
	22	5.4	6.5	8.9	12.3	6.7	4.4	0.3	0.1
11	10	4.3	4.6	7.8	7.2	5.2	3.4	0.4	0.1
	14	5.0	6.3	8.6	10.4	11.4	4.8	0.6	0.1
	20	5.4	6.4	10.6	14.2	10.6	6.5	0.5	0.1
	30	5.4	6.2	10.4	13.6	10.4	7.6	0.5	0.1
13	10	5.4	6.0	7.4	10.5	9.5	5.1	0.5	0.2
	14	5.8	6.6	8.8	12.4	10.0	7.0	0.7	0.1
	20	4.7	7.1	9.5	14.2	10.0	8.1	0.4	0.1
	32	4.9	7.6	10.9	13.0	9.0	8.2	0.6	0.3
15	10	2.8	4.3	6.2	8.8	7.9	5.0	0.3	0.1
	14	4.3	5.9	7.6	12.0	7.1	6.1	0.4	0.1
	20	5.5	7.4	9.4	15.1	F8.0	8.1	0.5	0.1
	32	5.3	6.0	8.7	14.2	8.3	6.5	0.4	0.3
17	14	4.3	4.7	8.2	9.7	6.8	6.9	0.6	0.1
	20	6.9	6.3	9.7	12.9	13.4	6.7	0.9	0.1
	28	7.6	7.7	11.6	13.9	12.5	6.8	1.3	0.5

Table 18
Wave Heights for the Offshore Breakwater Plan for Test Waves from Southwest, swl = 0.0 ft

Test Wave		Wave Height, ft							
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
7	8	1.0	2.4	3.4	4.5	3.5	3.2	0.1	0.1
	14	2.4	3.8	5.7	6.7	4.0	2.8	0.1	0.1
	20	3.5	5.4	6.1	8.2	6.0	3.3	0.2	0.1
9	10	2.1	3.4	5.4	4.1	3.8	3.3	0.1	0.1
	14	5.4	5.8	7.4	7.7	5.7	5.0	0.3	0.1
	22	5.2	6.5	8.4	11.7	6.8	5.7	0.3	0.1
11	6	1.7	2.3	2.1	2.3	1.5	2.9	0.1	0.1
	14	3.5	4.4	6.2	9.3	6.6	3.9	0.3	0.1
	20	3.9	5.7	9.7	12.2	8.4	5.0	0.4	0.1
	30	5.6	6.3	8.3	10.9	9.3	6.4	0.3	0.1
13	10	4.3	6.9	8.8	10.8	7.3	4.7	0.5	0.1
	14	3.9	5.8	9.4	12.0	7.9	6.1	0.5	0.1
	20	6.2	7.3	12.5	17.0	9.0	8.6	0.8	0.1
	32	7.0	9.8	11.2	14.5	13.5	7.5	0.5	0.1
15	10	3.7	4.6	5.4	9.3	4.9	5.3	0.2	0.1
	14	6.0	6.9	7.5	13.4	8.6	7.6	0.4	0.1
	20	4.7	5.6	8.7	14.0	8.0	7.0	0.3	0.1
	32	6.0	6.6	8.9	11.8	9.8	7.2	0.4	0.1
17	22	6.0	6.1	9.7	12.5	9.8	7.2	0.7	0.1

Table 19
Wave Heights for the Offshore Breakwater Plan for Test Waves from Northwest, swl = +7.0 ft

Test Wave		Wave Height, ft							
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
7	8	3.5	3.5	4.8	7.1	4.3	3.8	0.1	0.1
	14	7.2	7.8	10.2	11.7	11.7	14.0	0.5	0.1
	20	6.9	8.2	8.3	9.9	10.6	13.0	0.5	0.1
9	6	1.5	2.4	3.5	4.4	2.4	3.6	0.2	0.1
	12	2.5	4.6	4.8	6.5	4.2	4.5	0.3	0.1
	20	9.3	12.7	13.4	11.1	14.2	11.3	1.1	0.4
11	6	1.9	2.6	3.8	4.7	2.6	2.2	0.2	0.1
	14	5.8	9.2	7.9	10.3	8.8	7.3	0.4	0.2
	24	10.2	11.3	14.1	17.4	10.6	13.1	0.9	0.4
13	6	3.3	3.1	4.9	5.3	4.9	4.3	0.2	0.1
	14	8.6	8.7	11.2	9.4	7.0	10.0	0.8	0.4
	20	12.6	13.7	17.0	13.8	9.5	12.4	1.2	0.5
15	10	4.0	4.9	5.8	5.0	5.5	6.8	0.4	0.2
	14	5.4	7.2	7.6	8.5	6.3	10.5	0.6	0.2
	20	9.2	9.8	15.3	14.8	11.2	13.9	1.1	0.6
17	6	3.4	3.2	3.8	6.0	3.8	5.9	0.2	0.1
	12	7.1	6.5	8.7	8.8	5.7	9.7	0.6	0.2
	22	9.7	11.4	16.2	15.4	13.2	16.6	0.8	0.4
19	12	5.0	6.0	7.2	10.0	4.5	6.7	0.7	0.4

Table 20
Wave Heights for the Offshore Breakwater Plan for Test Waves from West-Northwest, swl = +7.0 ft

Test Wave		Wave Height, ft							
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
7	8	4.1	3.9	4.4	7.3	4.1	3.9	0.1	0.1
	16	7.9	11.1	13.5	13.4	12.7	8.1	0.8	0.1
9	6	1.6	3.5	3.3	4.6	1.8	2.9	0.1	0.1
	10	3.3	4.8	6.2	6.1	3.1	4/6	0.3	0.1
	18	10.0	14.9	16.7	16.0	15.8	10.2	0.9	0.4
11	6	1.6	1.9	3.1	4.3	1.8	3.1	0.1	0.1
	14	6.0	7.9	8.3	10.1	8.3	7.6	0.5	0.2
	24	8.8	11.3	13.2	13.0	13.0	14.7	0.4	0.1
13	6	2.5	3.3	4.4	6.0	3.9	5.2	0.2	0.1
	14	5.5	8.3	12.9	13.4	15.0	8.8	0.4	0.1
	22	10.8	13.9	15.7	14.0	12.9	15.2	0.7	0.2
15	10	4.7	6.0	6.4	8.0	8.2	5.9	0.5	0.2
	14	5.7	7.5	11.1	10.0	11.3	9.9	0.9	0.5
	20	10.1	11.4	17.0	17.0	19.2	12.0	1.0	0.4
	30	14.6	13.3	20.6	21.4	19.1	14.1	0.8	0.4
17	10	7.5	7.6	11.7	10.3	9.8	10.1	0.7	0.2
	20	12.8	13.2	17.4	19.6	22.6	15.3	1.4	0.7
	28	9.8	12.3	17.1	19.1	19.1	14.1	0.8	0.4
19	12	5.3	7.5	10.4	12.0	8.7	8.4	0.6	0.5
	22	11.8	14.1	15.5	17.8	17.4	11.8	1.3	0.6

Table 21
Wave Heights for the Offshore Breakwater Plan for Test Waves from west, swl = +7.0 ft

Test Wave		Wave Height, ft							
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
7	8	4.3	6.1	8.1	9.9	8.7	4.5	0.3	0.1
	14	8.6	9.6	12.4	16.1	12.2	5.7	0.6	0.2
	20	6.5	8.5	9.9	11.6	12.7	7.0	0.3	0.1
9	6	2.1	3.3	3.7	3.5	3.3	2.3	0.2	0.1
	14	3.7	6.2	8.4	9.1	6.4	3.9	0.3	0.1
	22	9.4	11.2	17.4	18.9	14.4	6.7	0.9	0.5
11	6	3.8	4.0	5.6	7.2	2.7	3.9	0.2	0.1
	14	9.3	12.3	12.5	16.3	13.0	11.5	0.8	0.5
	18	11.2	13.8	15.5	17.5	15.0	9.0	0.9	0.4
	30	7.1	10.2	11.3	16.9	12.1	10.6	0.4	0.2
13	6	5.4	5.4	5.6	4.9	5.3	4.4	0.3	0.2
	14	8.3	8.8	9.4	14.5	9.2	8.2	0.6	0.4
	20	9.6	10.0	11.4	14.1	11.3	12.0	0.7	0.5
	30	7.3	9.7	10.9	13.8	15.7	11.6	0.9	0.2
15	10	2.8	4.8	6.3	5.3	7.0	4.1	0.2	0.1
	14	3.5	4.1	6.6	7.5	8.0	6.3	0.4	0.1
	20	7.7	7.3	10.8	11.6	10.8	10.2	0.8	0.4
	30	8.8	9.1	12.8	16.4	10.6	8.1	0.8	0.4
17	10	3.0	3.3	6.1	5.1	5.0	4.6	0.2	0.1
	20	12.0	12.3	15.9	17.6	15.8	12.0	1.2	0.5
	28	8.5	9.7	13.1	14.9	11.9	15.3	0.8	0.5

Table 22
Wave Heights for the Offshore Breakwater Plan for Test Waves from West-Southwest, swl = +7.0 ft

Test Wave		Wave Height, ft							
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
7	8	2.3	2.9	2.9	5.1	3.1	3.3	0.2	0.1
	14	4.4	5.8	8.2	8.2	6.7	4.3	0.3	0.1
	20	4.3	5.4	8.6	9.9	7.9	4.8	0.2	0.1
9	6	1.8	2.8	2.8	3.3	3.5	3.3	0.2	0.1
	14	2.2	4.7	4.6	5.5	6.0	5.4	0.3	0.1
	22	5.0	6.8	7.6	9.7	9.3	4.7	0.4	0.2
11	10	3.9	5.6	5.5	5.1	6.3	4.3	0.3	0.1
	14	8.1	9.0	10.9	12.6	7.2	6.2	0.6	0.3
	20	8.2	10.7	9.8	13.9	10.1	9.5	0.5	0.2
	30	8.1	10.1	12.0	15.0	11.0	8.4	0.6	0.2
13	10	4.7	4.8	6.1	8.6	5.7	5.5	0.2	0.1
	14	8.9	7.3	10.5	11.2	6.2	8.3	0.5	0.3
	20	6.9	7.4	9.9	13.1	6.6	10.2	0.4	0.2
	32	11.4	11.1	13.8	17.0	11.8	9.6	0.5	0.1
15	10	3.9	4.5	5.4	6.3	7.3	5.3	0.3	0.2
	14	5.6	5.9	7.3	7.9	7.2	8.2	0.6	0.2
	20	6.6	7.7	9.8	11.9	7.5	9.8	0.4	0.2
	32	8.4	9.4	11.7	17.9	9.1	9.3	0.7	0.3
17	14	8.5	8.0	10.2	11.6	10.2	10.0	1.2	0.6
	20	7.3	10.1	12.6	15.6	13.8	10.0	1.0	0.4
	28	7.9	9.5	13.4	17.4	14.5	10.2	0.9	0.5

Table 23
Wave Heights for the Offshore Breakwater Plan for Test Waves from Southwest, swl = +7.0 ft

Test Wave		Wave Height, ft							
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
7	8	2.9	3.9	3.9	6.2	3.8	2.1	0.1	0.1
	14	2.4	3.7	5.2	3.8	4.7	3.4	0.1	0.1
	20	3.0	5.3	5.8	6.1	4.7	4.9	0.2	0.1
9	10	2.3	4.3	4.0	5.5	3.4	4.7	0.2	0.1
	14	2.6	6.1	5.3	7.7	5.7	4.8	0.3	0.2
	22	3.5	5.7	7.9	10.4	7.6	6.2	0.3	0.1
11	6	2.6	2.6	3.9	4.3	1.4	2.9	0.2	0.1
	14	6.0	7.4	7.7	8.0	4.9	5.2	0.4	0.2
	20	4.7	5.9	9.1	9.5	8.0	5.9	0.4	0.1
	30	6.9	9.2	8.3	14.1	12.2	6.0	0.4	0.2
13	10	5.5	6.0	6.3	11.8	7.1	6.4	0.5	0.2
	14	5.7	5.5	10.3	13.7	7.9	7.4	0.6	0.2
	20	5.7	8.1	12.1	12.6	7.5	7.9	0.5	0.2
	32	8.7	10.3	15.4	16.8	10.0	10.6	0.8	0.2
15	10	4.3	4.5	5.2	8.0	7.3	6.9	0.4	0.2
	14	6.3	6.9	7.5	9.3	6.8	7.3	0.9	0.3
	20	8.1	8.6	10.2	14.0	8.6	9.4	1.1	0.6
	32	7.9	10.2	10.7	17.2	9.2	9.9	0.8	0.3
17	22	6.9	8.3	10.7	14.9	13.8	9.2	0.7	0.3

Photo 1. Typical wave patterns for existing conditions; 9-sec, 20-ft waves from northwest; swl = 0.0 ft

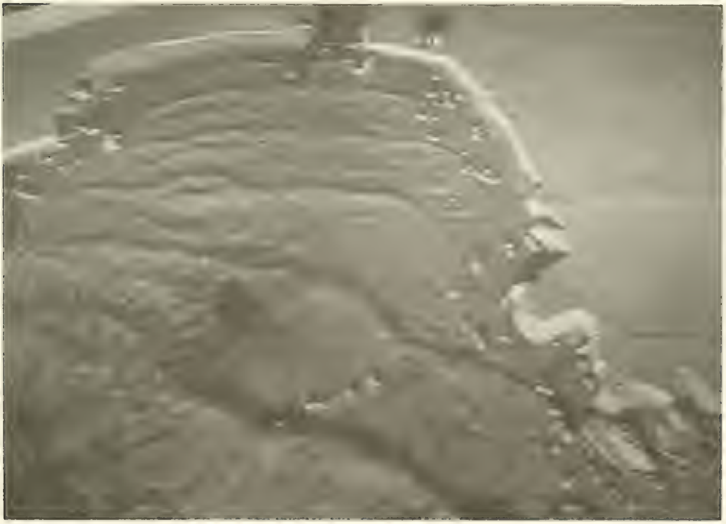


Photo 2. Typical wave patterns for existing conditions; 15-sec, 14-ft waves from northwest; swl = 0.0 ft

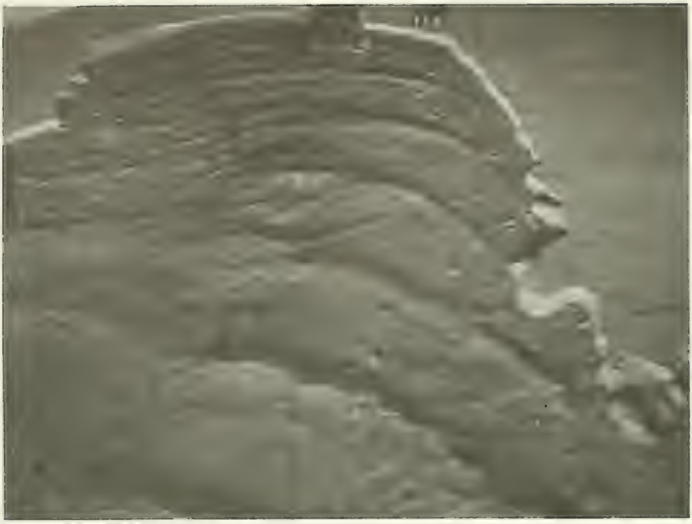


Photo 3. Typical wave patterns for exixting conditions; 13-sec, 14-ft waves from northwest; swl = +7.0 ft

Photo 4. Typical wave patterns for existing conditions; 17-sec, 22-ft waves from northwest; swl = +7.0 ft

Photo 5. Typical wave patterns for existing conditions; 15-sec, 14-ft waves from west-northwest; swl = 0.0 ft

Photo 6. Typical wave patterns for existing conditions; 17-sec, 20-ft waves from west-northwest; swl = 0.0 ft

Photo 7. Typical wave patterns for existing conditions; 13-sec, 14-ft waves from west-northwest; swl = +7.0 ft

Photo 8. Typical wave patterns for existing conditions; 15-sec, 20-ft waves from west-northwest; swl = +7.0 ft

Photo 9. Typical wave patterns for existing conditions; 13-sec, 20-ft waves from west; swl = 0.0 ft

Photo 10. Typical wave patterns for existing conditions; 15-sec, 14-ft waves from west; swl = 0.0 ft

Photo 11. Typical wave patterns for existing conditions; 13-sec, 14-ft waves from west; swl = +7.0 ft

Photo 12. Typical wave patterns for existing conditions; 15-sec, 20-ft waves from west; swl = +7.0 ft

Photo 13. Typical wave patterns for existing conditions; 11-sec, 20-ft waves from west-southwest; swl = 0.0 ft

Photo 14. Typical wave patterns for existing conditions; 13-sec, 14-ft waves from west-southwest; swl = 0.0 ft

Photo 15. Typical wave patterns for existing conditions; 13-sec, 20-ft waves from west-southwest; swl = +7.0 ft

Photo 16. Typical wave patterns for existing conditions; 15-sec, 14-ft waves from west-southwest; swl = +7.0 ft

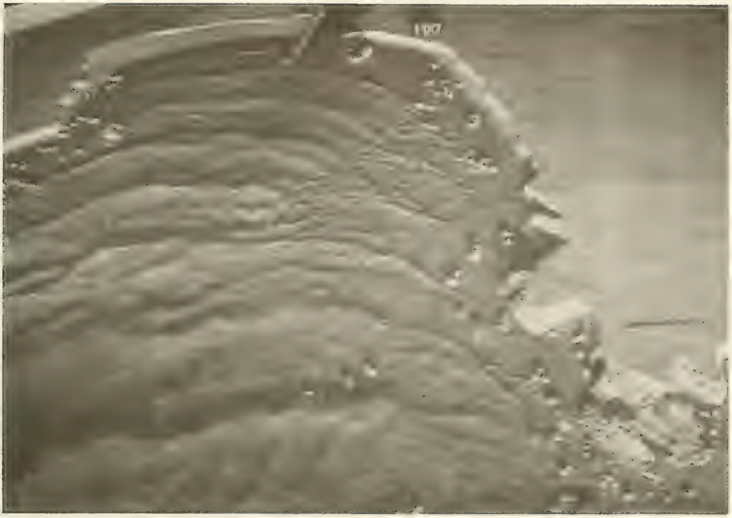


Photo 17. Typical wave patterns for existing conditions; 11-sec, 20-ft waves from southwest; swl = 0.0 ft

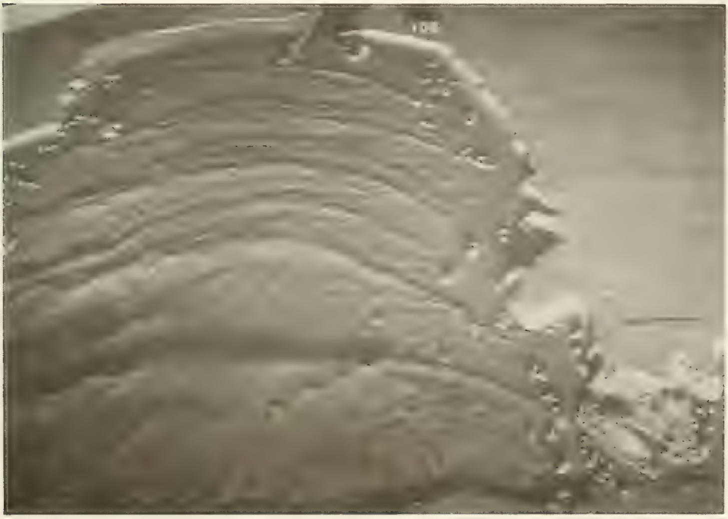


Photo 18. Typical wave patterns for existing conditions; 15-sec, 14-ft waves from southwest; swl = 0.0 ft

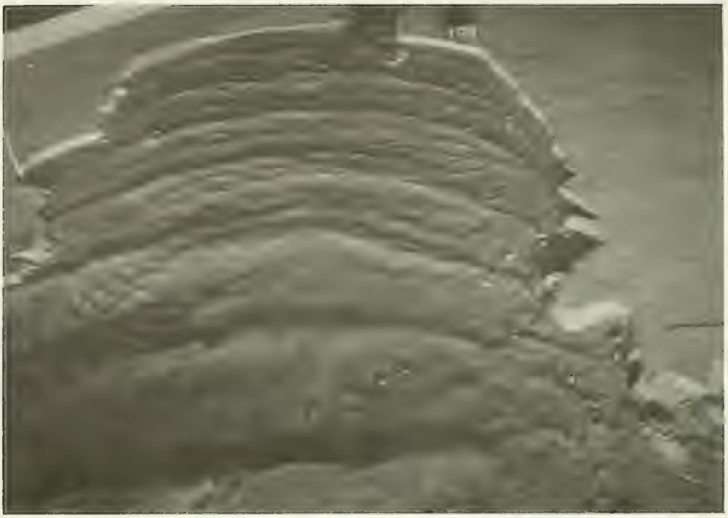


Photo 19. Typical wave patterns for existing conditions; 13-sec, 14-ft waves from southwest; swl = +7.0 ft

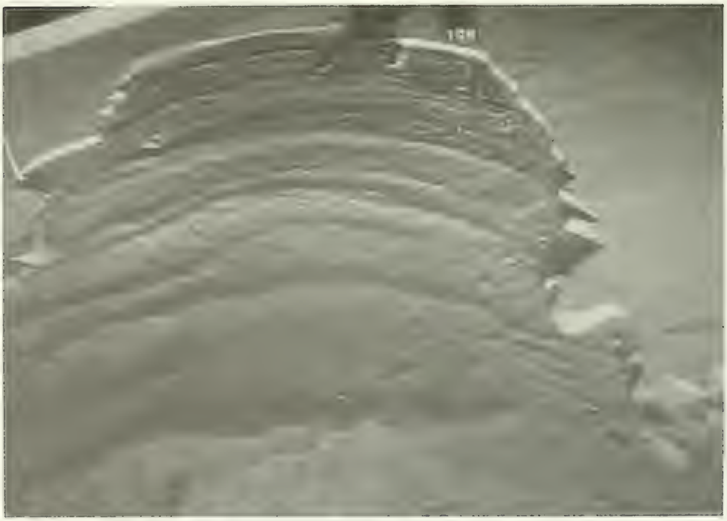


Photo 20. Typical wave patterns for existing conditions; 15-sec, 20-ft waves from southwest; swl = +7.0 ft

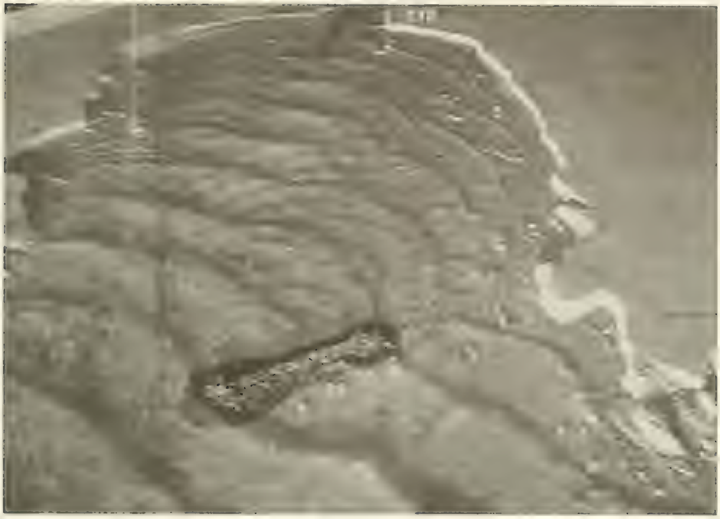


Photo 21. Typical wave patterns for the offshore breakwater plan; 9-sec, 20-ft waves from northwest; swl = 0.0 ft

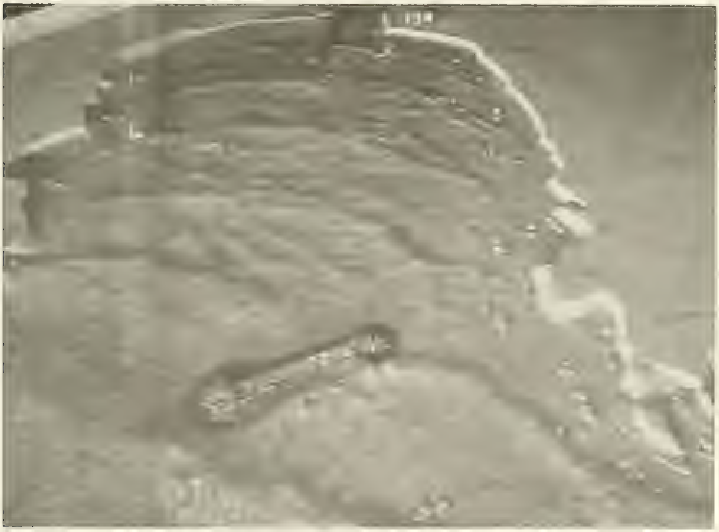


Photo 22. Typical wave patterns for the offshore breakwater plan; 15-sec, 14-ft waves from northwest; swl = 0.0 ft

Photo 23. Typical wave patterns for the offshore breakwater plan; 13-sec, 14-ft waves from northwest; swl = +7.0 ft

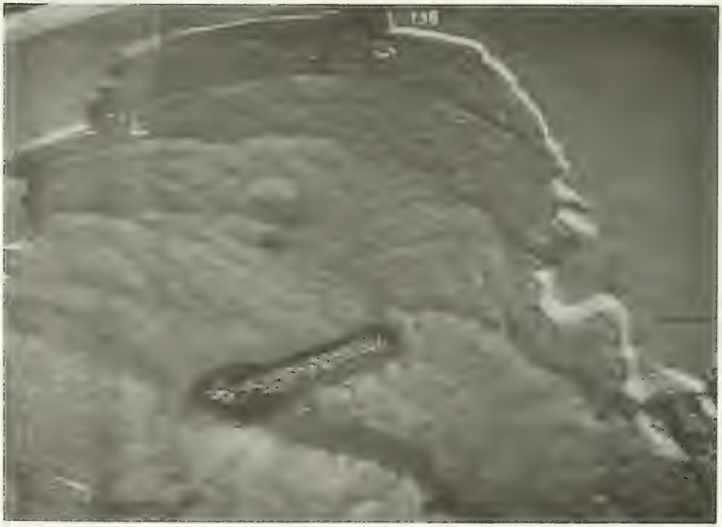


Photo 24. Typical wave patterns for the offshore breakwater plan; 17-sec, 22-ft waves from northwest; swl = +7.0 ft

Photo 25. Typical wave patterns for the offshore breakwater plan; 13-sec, 20-ft waves from west; swl = 0.0 ft

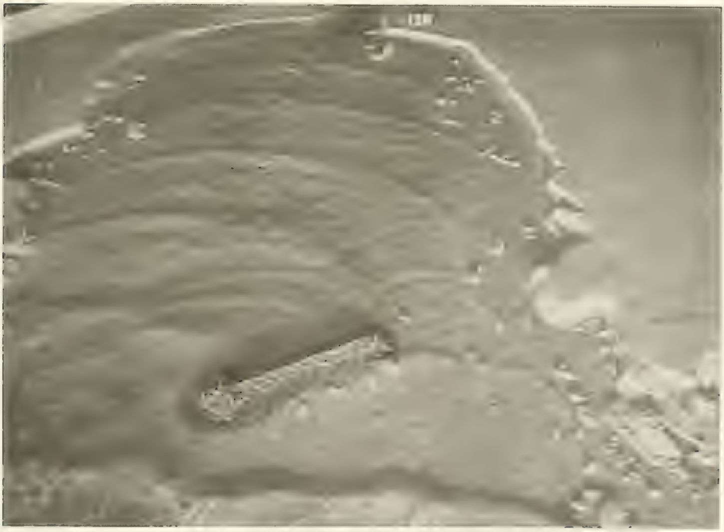


Photo 26. Typical wave patterns for the offshore breakwater plan; 15-sec, 14-ft waves from west; swl = 0.0 ft

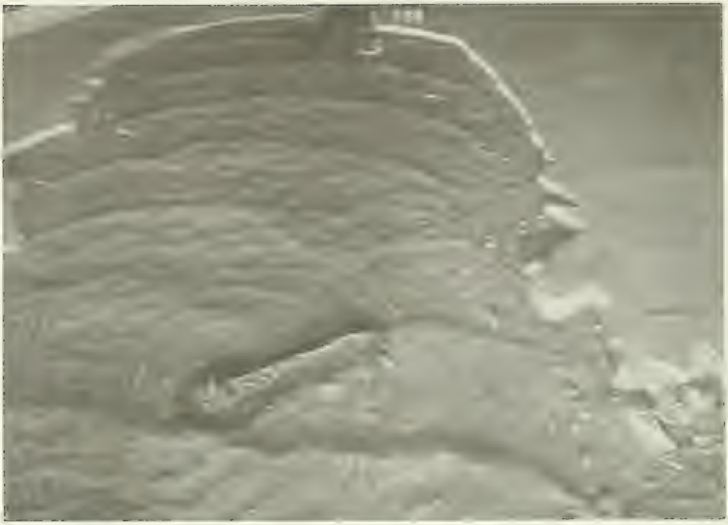


Photo 27. Typical wave patterns for the offshore breakwater plan; 13-sec, 14-ft waves from west; swl = +7.0 ft

Photo 28. Typical wave patterns for the offshore breakwater plan; 15-sec, 20-ft waves from west; swl = +7.0 ft

Photo 29. Typical wave patterns for the offshore breakwater plan; 11-sec, 20-ft waves from west-southwest; swl = 0.0 ft

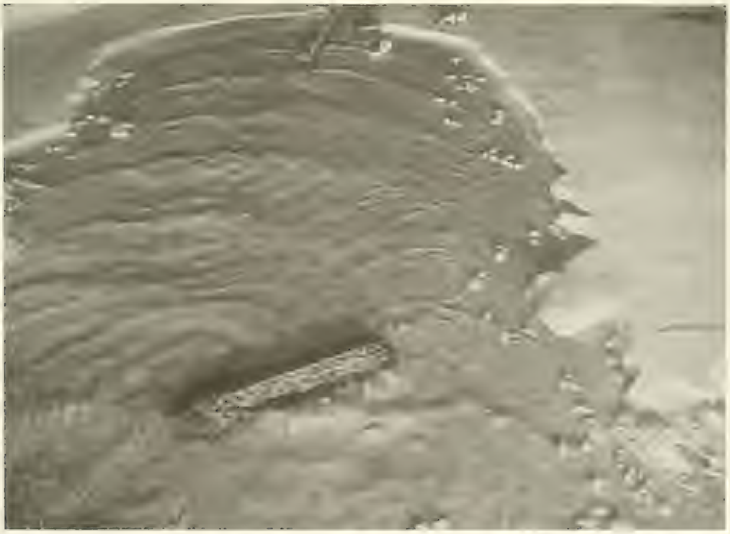


Photo 30. Typical wave patterns for the offshore breakwater plan; 13-sec, 14-ft waves from west-southwest; swl = 0.0 ft

Photo 31. Typical wave patterns for the offshore breakwater plan; 13-sec, 20-ft waves from west-southwest; swl = +7.0 ft

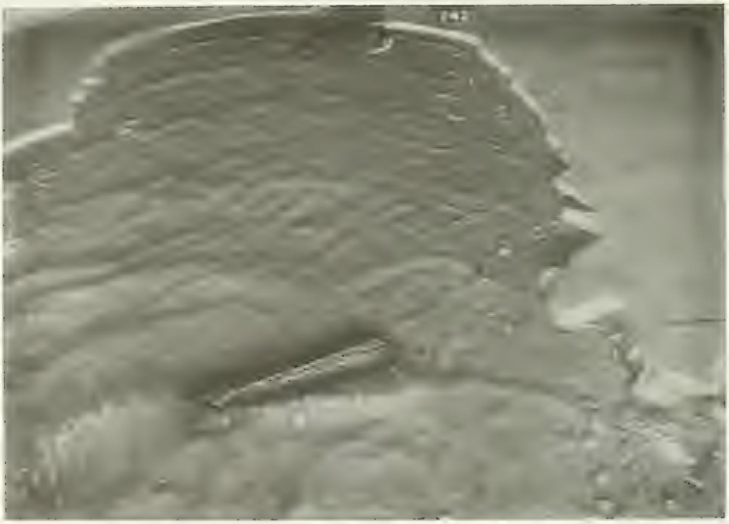


Photo 32. Typical wave patterns for the offshore breakwater plan; 15-sec, 14-ft waves from west-southwest; swl = +7.0 ft

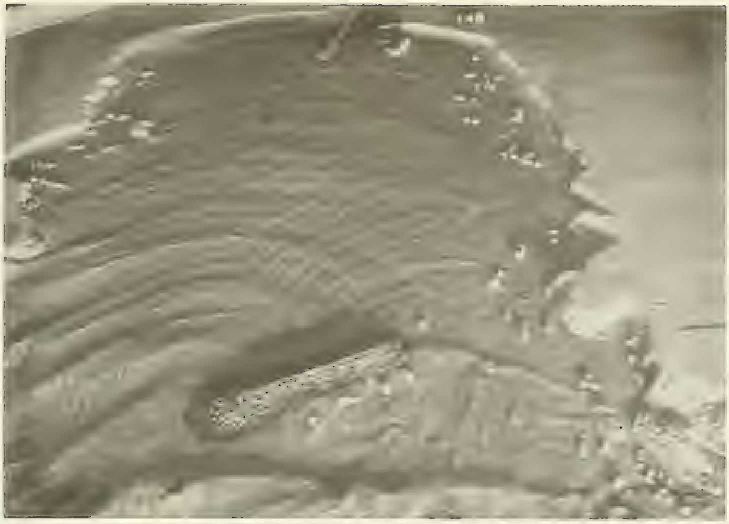


Photo 33. Typical wave patterns for the offshore breakwater plan; 11-sec, 20-ft waves from southwest; swl = 0.0 ft

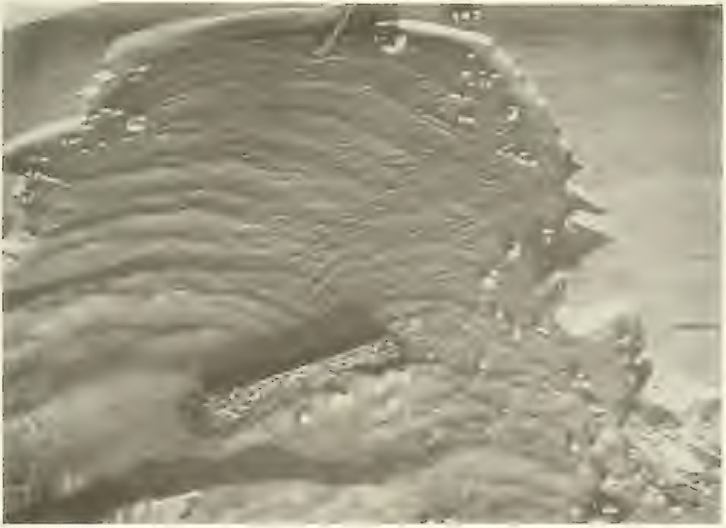


Photo 34. Typical wave patterns for the offshore breakwater plan; 15-sec, 14-ft waves from southwest; swl = 0.0 ft

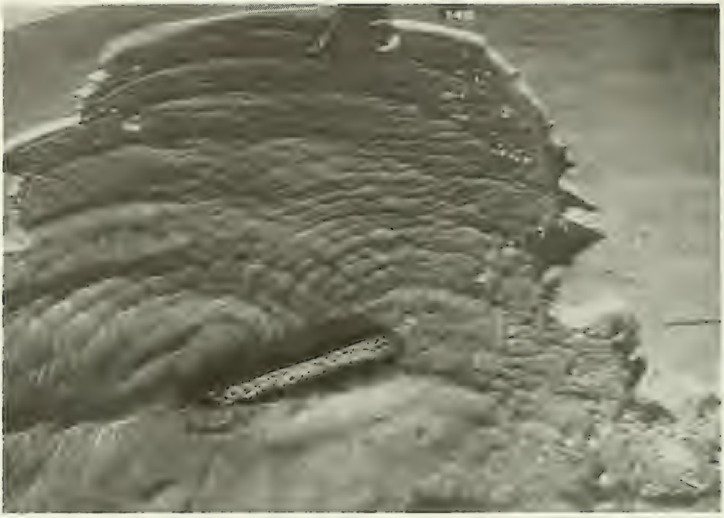


Photo 35. Typical wave patterns for the offshore breakwater plan; 13-sec, 14-ft waves from southwest; swl = +7.0 ft

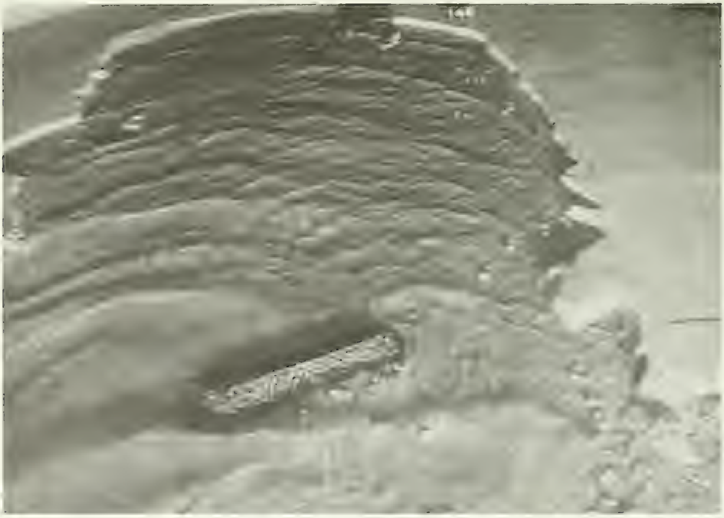


Photo 36. Typical wave patterns for the offshore breakwater plan; 15-sec, 20-ft waves from southwest; swl = +7.0 ft

Photo 37. Typical wave patterns for the offshore breakwater plan; 15-sec, 14-ft waves from west-northwest; swl = 0.0 ft

Photo 38. Typical wave patterns for the offshore breakwater plan; 17-sec, 20-ft waves from west-northwest; swl = 0.0 ft

Photo 39. Typical wave patterns for the offshore breakwater plan; 13-sec, 14-ft waves from west-northwest; swl = +7.0 ft

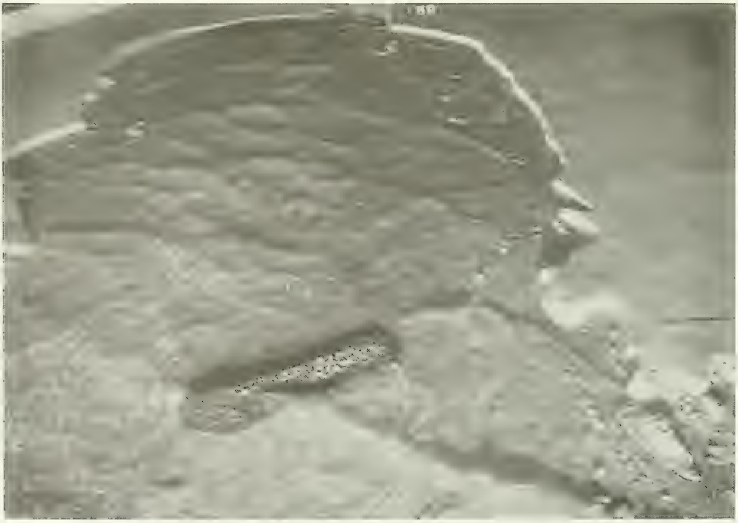


Photo 40. Typical wave patterns for the offshore breakwater plan; 15-sec, 20-ft waves from west-northwest; swl = +7.0 ft

Photo 41. Riverine sediment patterns for existing conditions; 7,000-cfs river discharge

Photo 42. Riverine sediment patterns for existing conditions; 20,000-cfs river discharge

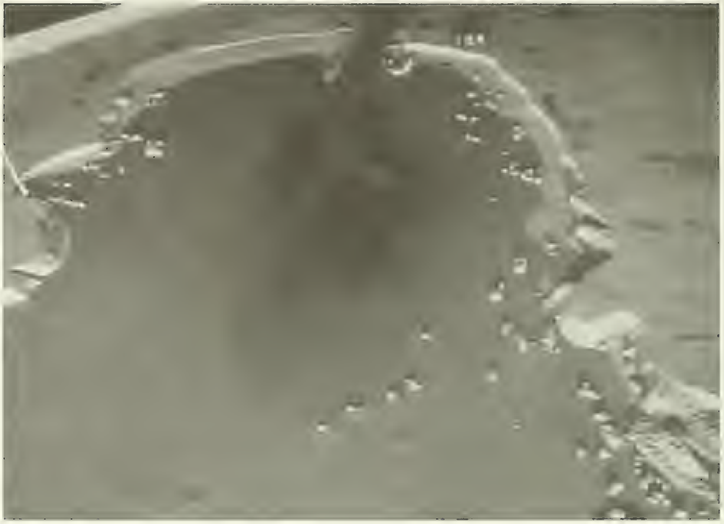


Photo 43. Riverine sediment patterns for existing conditions; 27,000-cfs river discharge

Photo 44. Riverine sediment patterns for existing conditions; 33,000-cfs river discharge

Photo 45. Riverine sediment patterns for existing conditions; 41,000-cfs river discharge

Photo 46. Riverine sediment patterns for offshore breakwater plan; 7,000-cfs river discharge

Photo 47. Riverine sediment patterns for offshore breakwater plan; 20,000-cfs river discharge

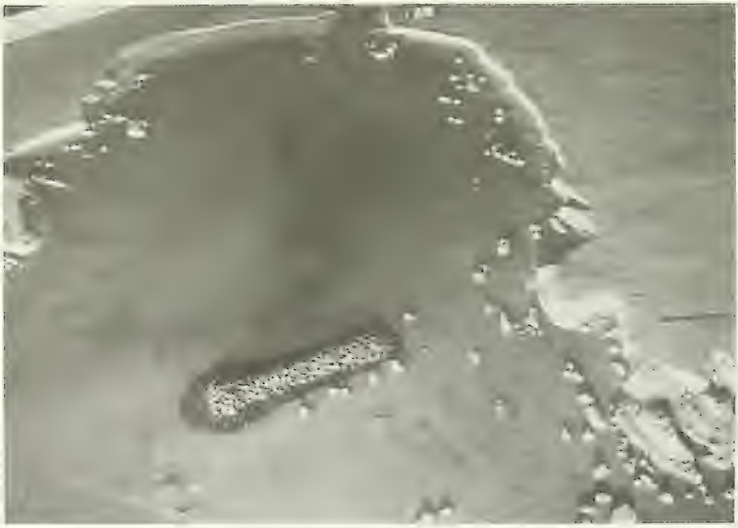


Photo 48. Riverine sediment patterns for offshore breakwater plan; 27,000-cfs river discharge

Photo 49. Riverine sediment patterns for offshore breakwater plan; 33,000-cfs river discharge

Photo 50. Riverine sediment patterns for offshore breakwater plan; 41,000-cfs river discharge

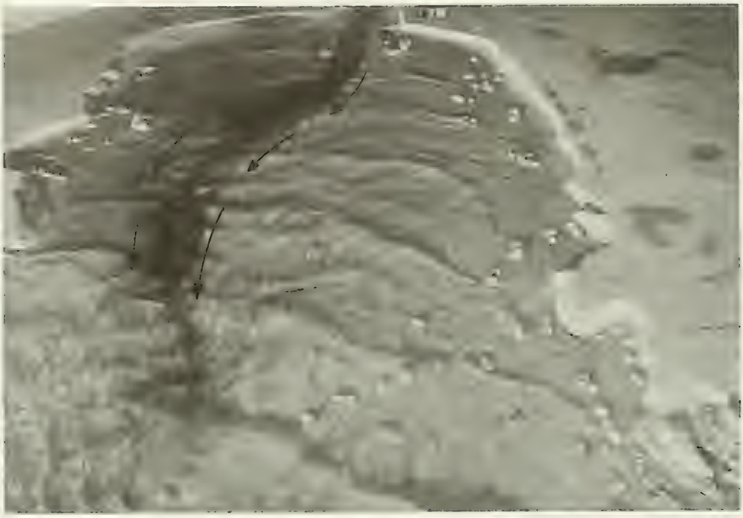


Photo 51. Riverine sediment tracer patterns for existing conditions; 13-sec, 14-ft waves from west-northwest; swl = 0.0 ft, 20,000-cfs river discharge

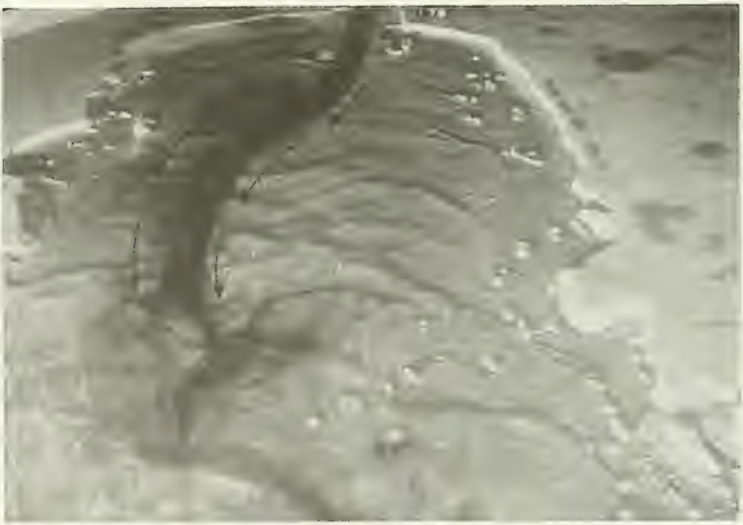


Photo 52. Riverine sediment tracer patterns for existing conditions; 13-sec, 14-ft waves from west-northwest; swl = 0.0 ft, 27,000-cfs river discharge

Photo 53. Riverine sediment tracer patterns for existing conditions; 13-sec, 14-ft waves from west-northwest; swl = 0.0 ft, 33,000-cfs river discharge

Photo 54. Riverine sediment tracer patterns for existing conditions; 13-sec, 14-ft waves from west-northwest; swl = 0.0 ft, 41,000-cfs river discharge

Photo 55. Riverine sediment tracer patterns for existing conditions; 15-sec, 20-ft waves from west-northwest; swl = 0.0 ft, 20,000-cfs river discharge

Photo 56. Riverine sediment tracer patterns for existing conditions; 15-sec, 20-ft waves from west-northwest; swl = 0.0 ft, 27,000-cfs river discharge

Photo 57. Riverine sediment tracer patterns for existing conditions; 15-sec, 20-ft waves from west-northwest; swl = 0.0 ft, 33,000-cfs river discharge

Photo 58. Riverine sediment tracer patterns for existing conditions; 15-sec, 20-ft waves from west-northwest; swl = 0.0 ft, 41,000-cfs river discharge

Photo 59. Riverine sediment tracer patterns for existing conditions; 13-sec, 14-ft waves from west; swl = 0.0 ft, 20,000-cfs river discharge

Photo 60. Riverine sediment tracer patterns for existing conditions; 13-sec, 14-ft waves from west; swl = 0.0 ft, 27,000-cfs river discharge

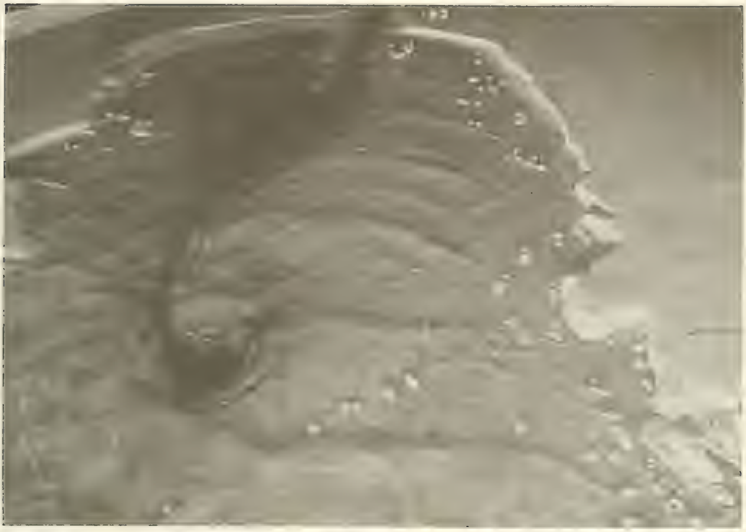


Photo 61. Riverine sediment tracer patterns for existing conditions; 13-sec, 14-ft waves from west; swl = 0.0 ft, 33,000-cfs river discharge

Photo 62. Riverine sediment tracer patterns for existing conditions; 13-sec, 14-ft waves from west; swl = 0.0 ft, 41,000-cfs river discharge

Photo 63. Riverine sediment tracer patterns for existing conditions; 15-sec, 20-ft waves from west; swl = 0.0 ft, 20,000-cfs river discharge

Photo 64. Riverine sediment tracer patterns for existing conditions; 15-sec, 20-ft waves from west; swl = 0.0 ft, 27,000-cfs river discharge

Photo 65. Riverine sediment tracer patterns for existing conditions; 15-sec, 20-ft waves from west; swl = 0.0 ft, 33,000-cfs river discharge

Photo 66. Riverine sediment tracer patterns for existing conditions; 15-sec, 20-ft waves from west; swl = 0.0 ft, 41,000-cfs river discharge

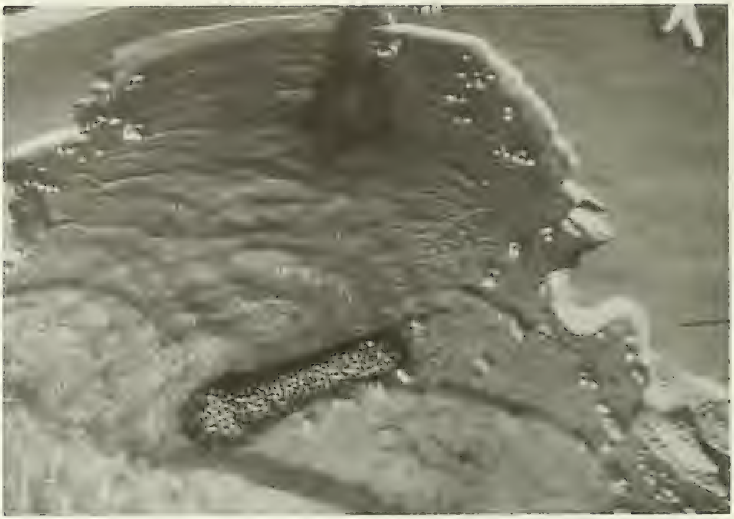


Photo 67. Riverine sediment tracer patterns for the offshore breakwater plan; 13-sec, 14-ft waves from west-northwest; swl = 0.0 ft, 20,000-cfs river discharge

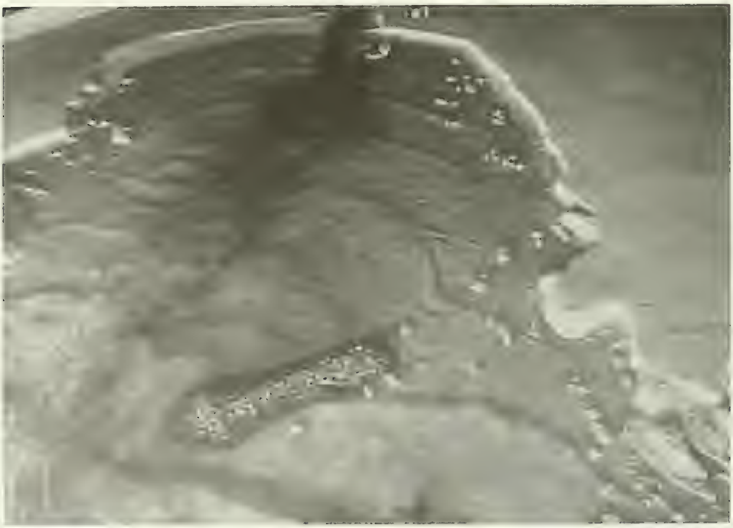


Photo 68. Riverine sediment tracer patterns for the offshore breakwater plan; 13-sec, 14-ft waves from west-northwest; swl = 0.0 ft, 27,000-cfs river discharge

Photo 69. Riverine sediment tracer patterns for the offshore breakwater plan; 13-sec, 14-ft waves from west-northwest; swl = 0.0 ft, 33,000-cfs river discharge

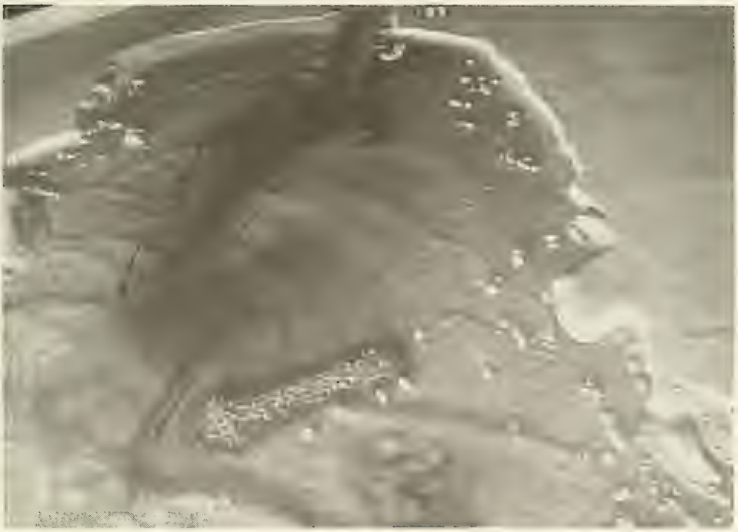


Photo 70. Riverine sediment tracer patterns for the offshore breakwater plan; 13-sec, 14-ft waves from west-northwest; swl = 0.0 ft, 41,000-cfs river discharge

Photo 71. Riverine sediment tracer patterns for the offshore breakwater plan; 15-sec, 20-ft waves from west-northwest; swl = 0.0 ft, 20,000-cfs river discharge

Photo 72. Riverine sediment tracer patterns for the offshore breakwater plan; 15-sec, 20-ft waves from west-northwest; swl = 0.0 ft, 27,000-cfs river discharge

Photo 73. Riverine sediment tracer patterns for the offshore breakwater plan; 15-sec, 20-ft waves from west-northwest; swl = 0.0 ft, 33,000-cfs river discharge

Photo 74. Riverine sediment tracer patterns for the offshore breakwater plan; 15-sec, 20-ft waves from west-northwest; swl = 0.0 ft, 41,000-cfs river discharge

Photo 75. Riverine sediment tracer patterns for the offshore breakwater plan; 13-sec, 14-ft waves from west; swl = 0.0 ft, 20,000-cfs river discharge

Photo 76. Riverine sediment tracer patterns for the offshore breakwater plan; 13-sec, 14-ft waves from west; swl = 0.0 ft, 27,000-cfs river discharge

Photo 77. Riverine sediment tracer patterns for the offshore breakwater plan; 13-sec, 14-ft waves from west; swl = 0.0 ft, 33,000-cfs river discharge

Photo 78. Riverine sediment tracer patterns for the offshore breakwater plan; 13-sec, 14-ft waves from west; swl = 0.0 ft, 41,000-cfs river discharge

Photo 79. Riverine sediment tracer patterns for the offshore breakwater plan; 15-sec, 20-ft waves from west; swl = 0.0 ft, 20,000-cfs river discharge

Photo 80. Riverine sediment tracer patterns for the offshore breakwater plan; 15-sec, 20-ft waves from west; swl = 0.0 ft, 27,000-cfs river discharge

Photo 81. Riverine sediment tracer patterns for the offshore breakwater plan; 15-sec, 20-ft waves from west; swl = 0.0 ft, 33,000-cfs river discharge

Photo 82. Riverine sediment tracer patterns for the offshore breakwater plan; 15-sec, 20-ft waves from west; swl = 0.0 ft, 41,000-cfs river discharge

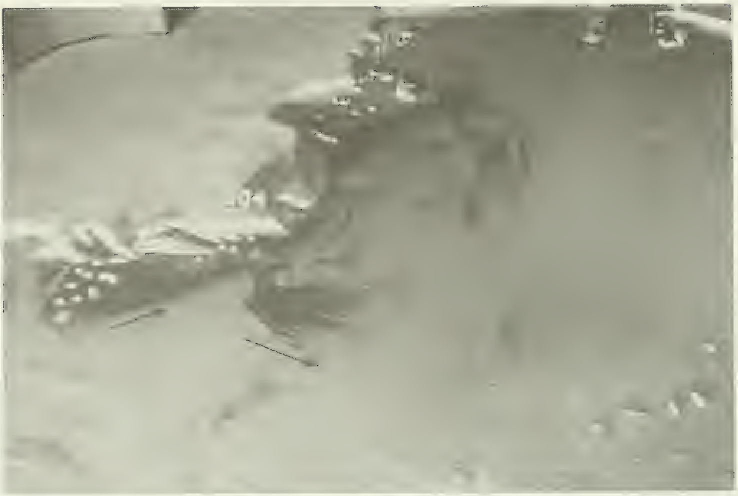


Photo 83. General movement of tracer material and subsequent deposits for existing conditions; 13-sec, 14-ft waves from northwest; swl = 0.0 ft

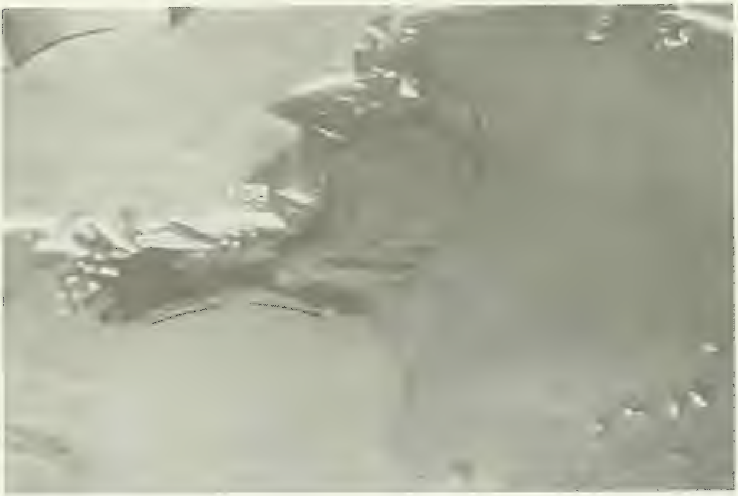


Photo 84. General movement of tracer material and subsequent deposits for existing conditions; 15-sec, 20-ft waves from northwest; swl = 0.0 ft

Photo 85. General movement of tracer material and subsequent deposits for existing conditions; 13-sec, 14-ft waves from southwest; swl = 0.0 ft

Photo 86. General movement of tracer material and subsequent deposits for existing conditions; 15-sec, 20-ft waves from southwest; swl = 0.0 ft

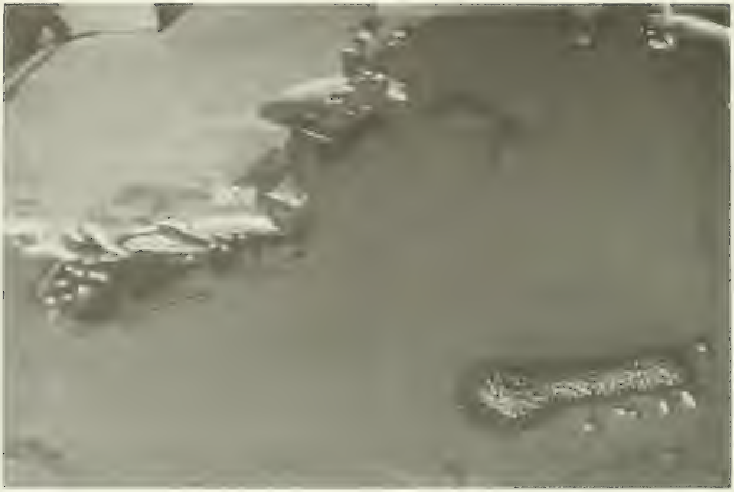


Photo 87. General movement of tracer material and subsequent deposits for the offshore breakwater plan; 13-sec, 14-ft waves from northwest; swl = 0.0 ft

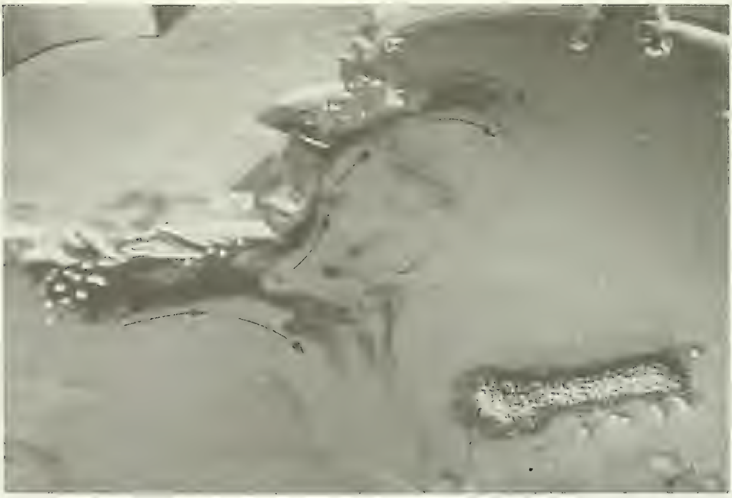
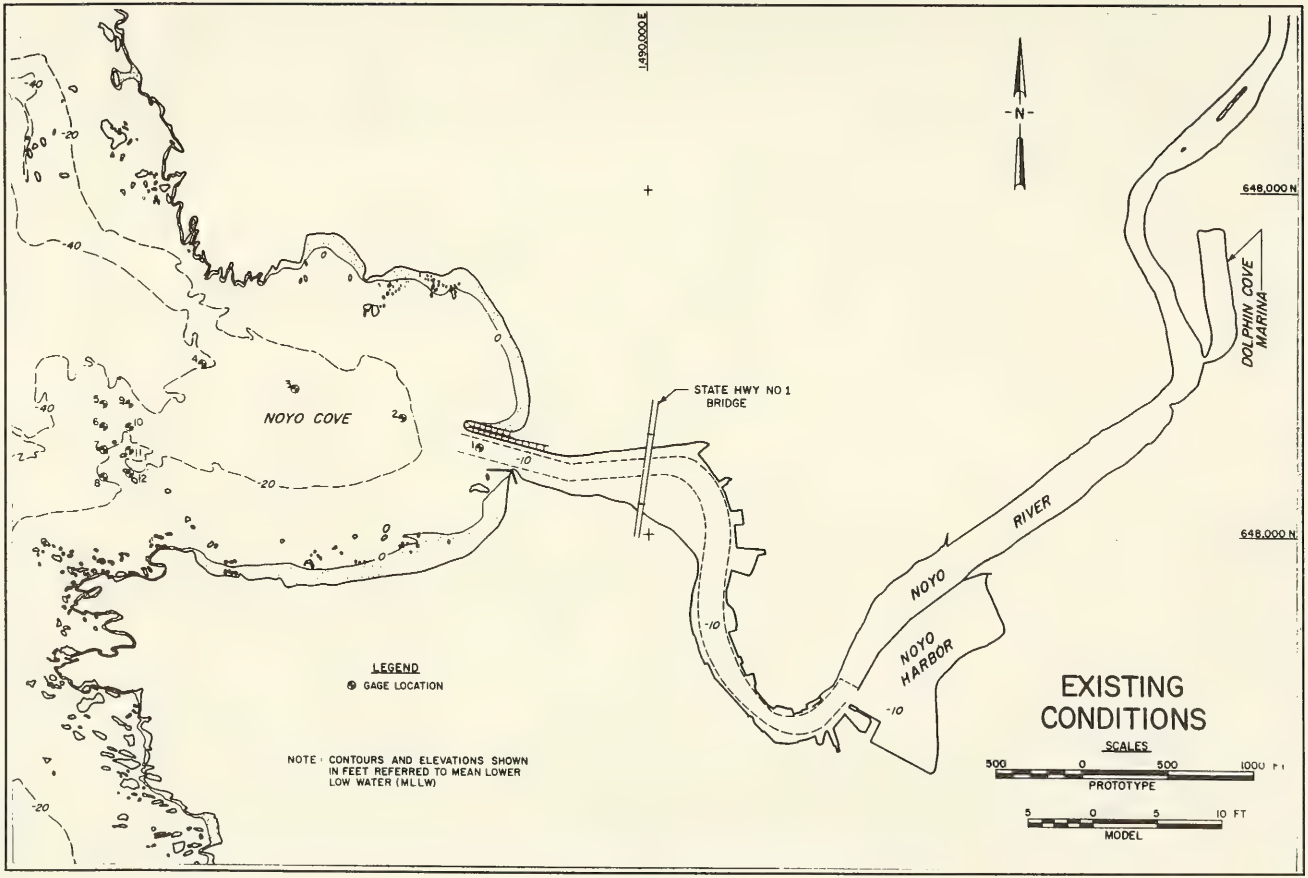


Photo 88. General movement of tracer material and subsequent deposits for the offshore breakwater plan; 15-sec, 20-ft waves from northwest; swl = 0.0 ft

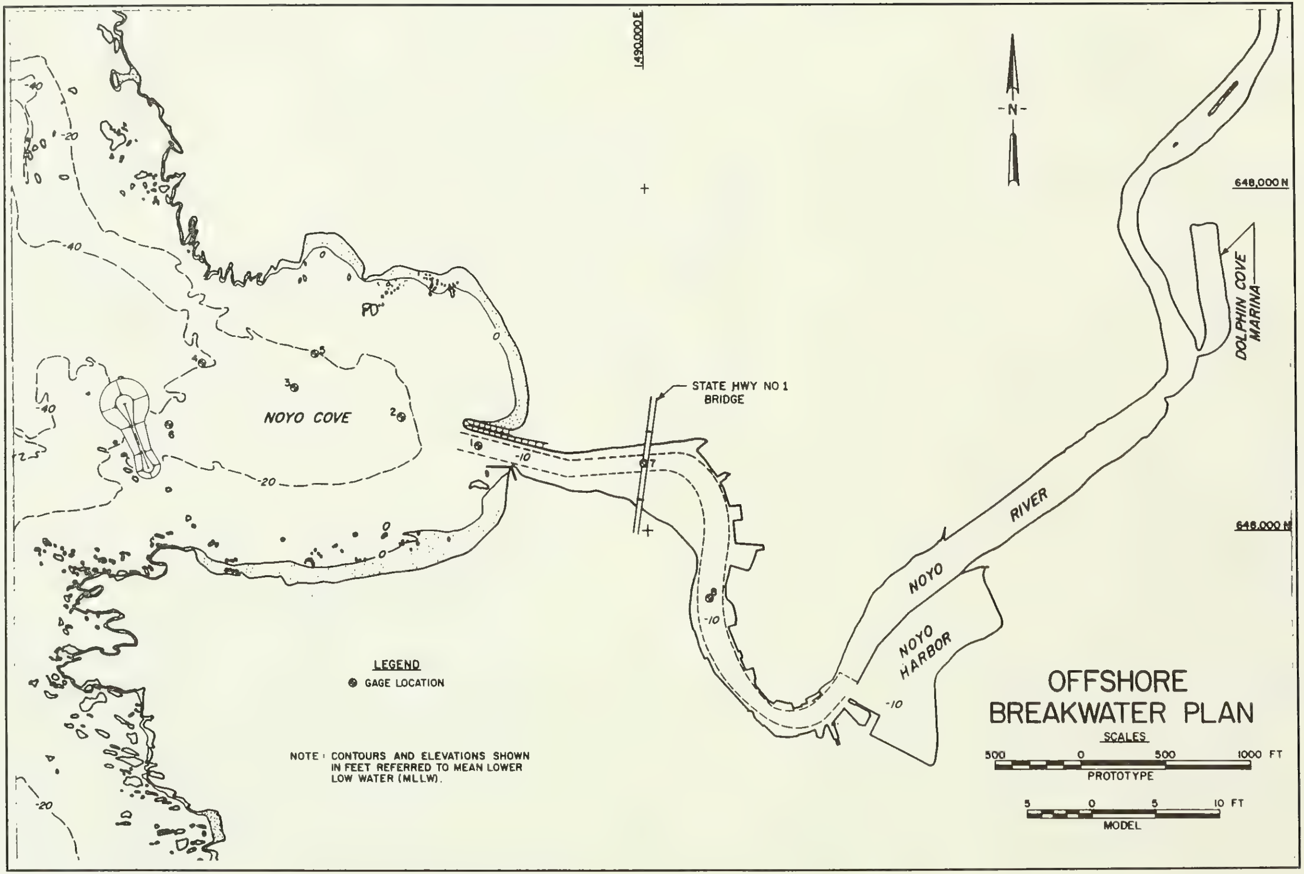
Photo 89. General movement of tracer material and subsequent deposits for the offshore breakwater plan; 13-sec, 14-ft waves from southwest; swl = 0.0 ft

Photo 90. General movement of tracer material and subsequent deposits for the offshore breakwater plan; 15-sec, 20-ft waves from southwest; swl = 0.0 ft



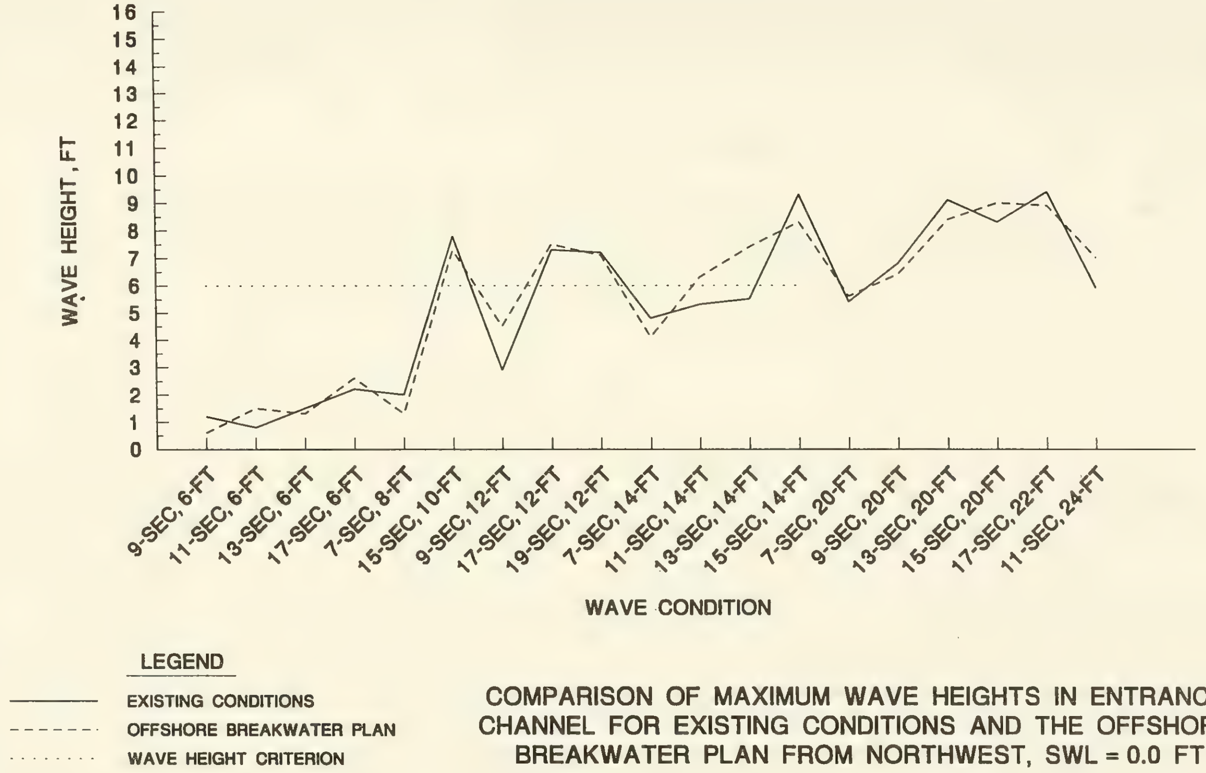
EXISTING CONDITIONS
SCALES
500 0 500 1000 FT
PROTOTYPE
5 0 5 10 FT
MODEL
NOYO COVE
NOYO RIVER
NOYO HARBOR
DOLPHIN COVE MARINA
STATE HWY NO 1 BRIDGE
648,000 N
1,490,000 E
N
LEGEND
GAGE LOCATION
NOTE: CONTOURS AND ELEVATIONS SHOWN IN FEET REFERRED TO MEAN LOWER LOW WATER (MLLW)

Plate 1

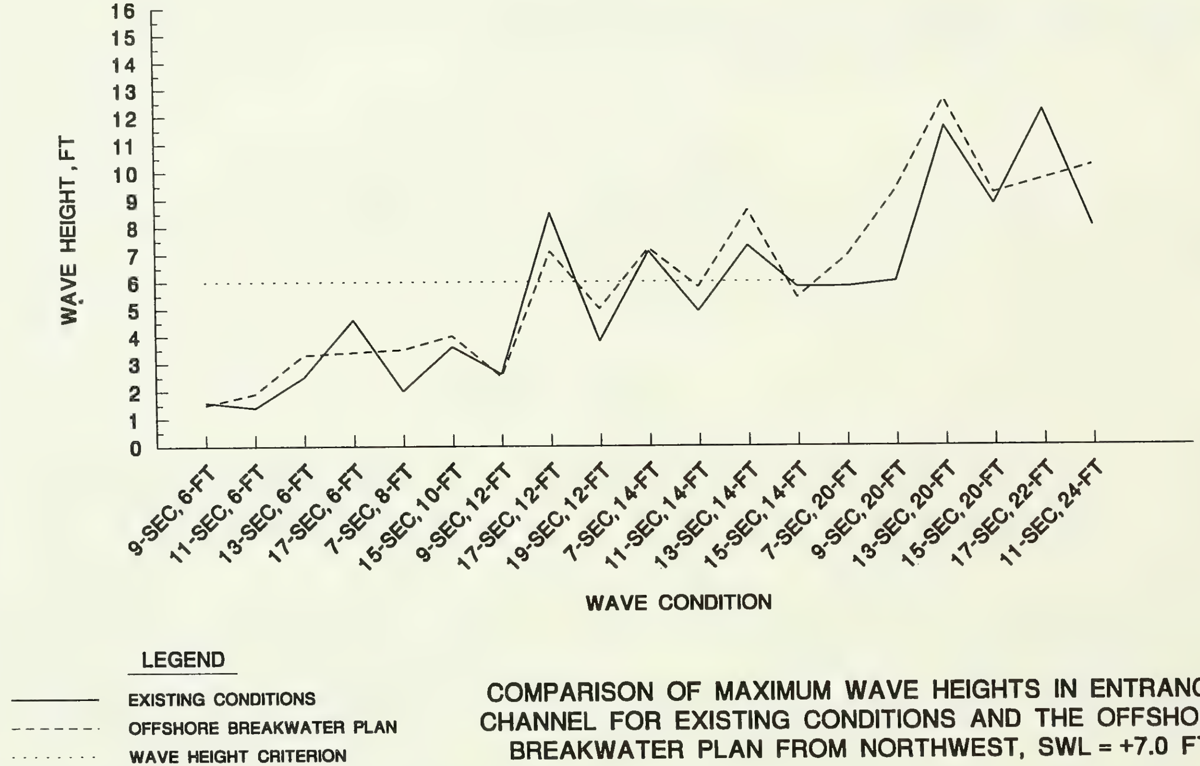


OFFSHORE
BREAKWATER PLAN
SCALES
500
0
500
1000 FT
PROTOTYPE
5
0
5
10 FT
MODEL
LEGEND
GAGE LOCATION
NOTE: CONTOURS AND ELEVATIONS SHOWN IN FEET REFERRED TO MEAN LOWER LOW WATER (MLLW).
NOYO COVE
STATE HWY NO 1 BRIDGE
NOYO RIVER
NOYO HARBOR
DOLPHIN COVE MARINA
648,000 N
648,000 N
1,490,000 E
N
-10
-20
-40
0

Plate 2

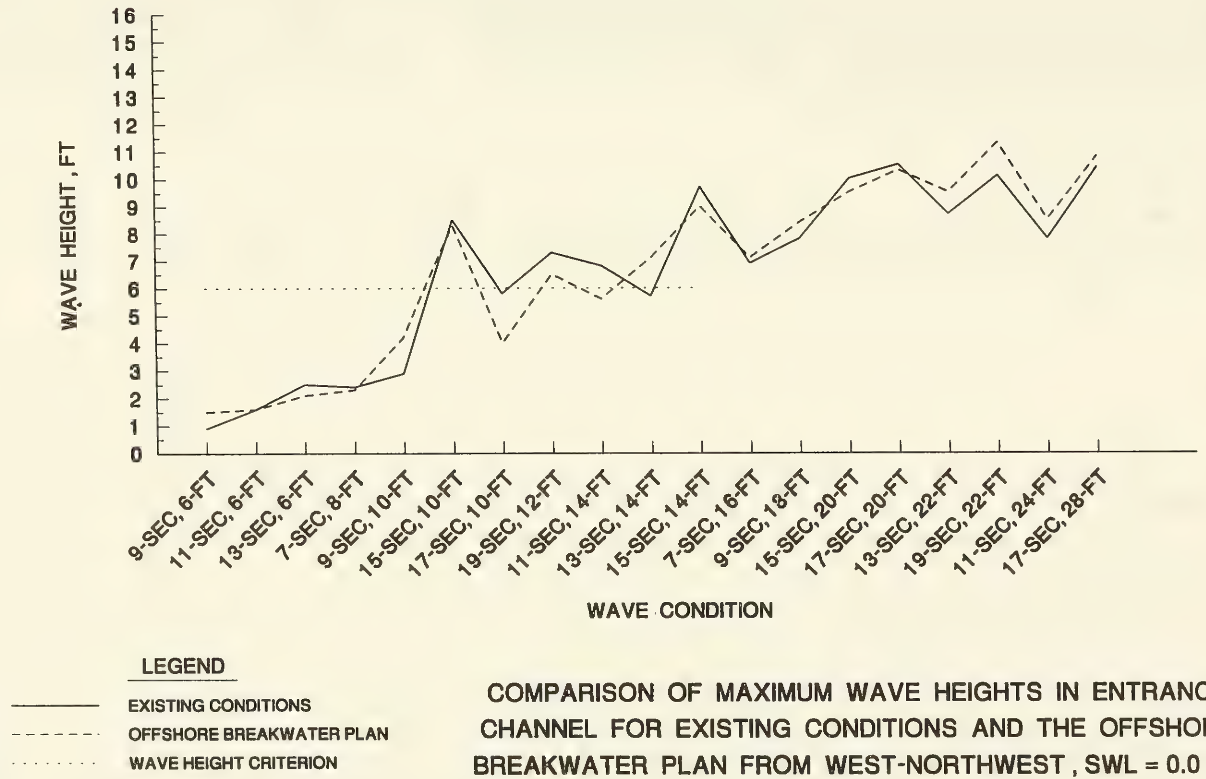


COMPARISON OF MAXIMUM WAVE HEIGHTS IN ENTRANCE CHANNEL FOR EXISTING CONDITIONS AND THE OFFSHORE BREAKWATER PLAN FROM NORTHWEST, SWL = 0.0 FT

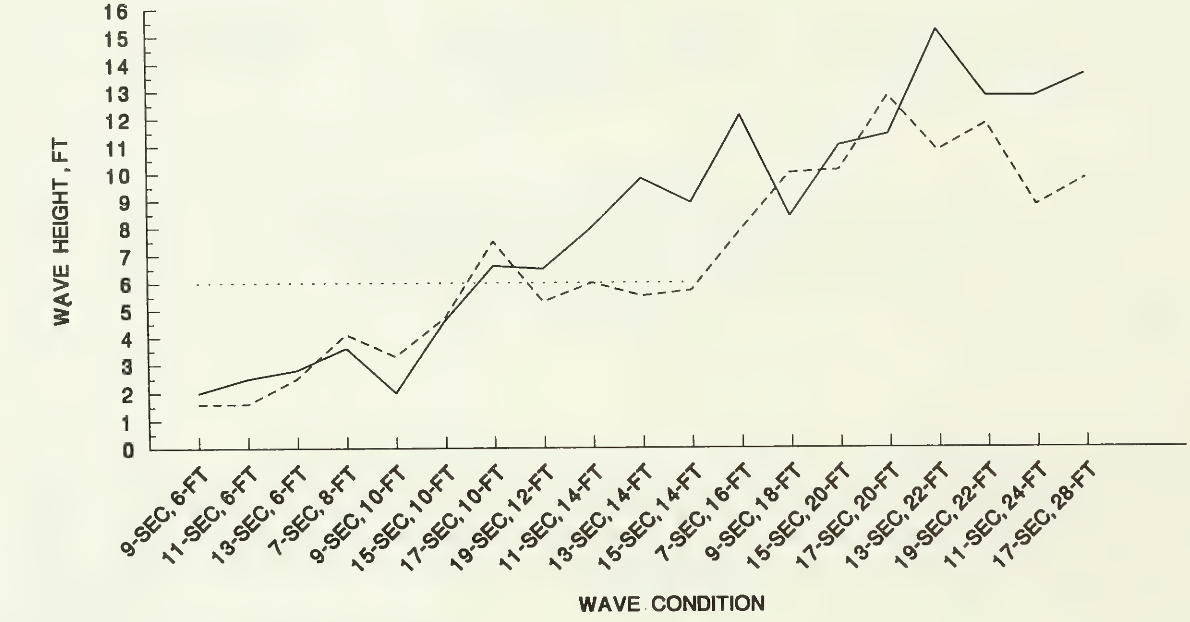


COMPARISON OF MAXIMUM WAVE HEIGHTS IN ENTRANCE CHANNEL FOR EXISTING CONDITIONS AND THE OFFSHORE BREAKWATER PLAN FROM NORTHWEST, SWL = +7.0 FT

Plate 4



COMPARISON OF MAXIMUM WAVE HEIGHTS IN ENTRANCE CHANNEL FOR EXISTING CONDITIONS AND THE OFFSHORE BREAKWATER PLAN FROM WEST-NORTHWEST, SWL = 0.0 FT



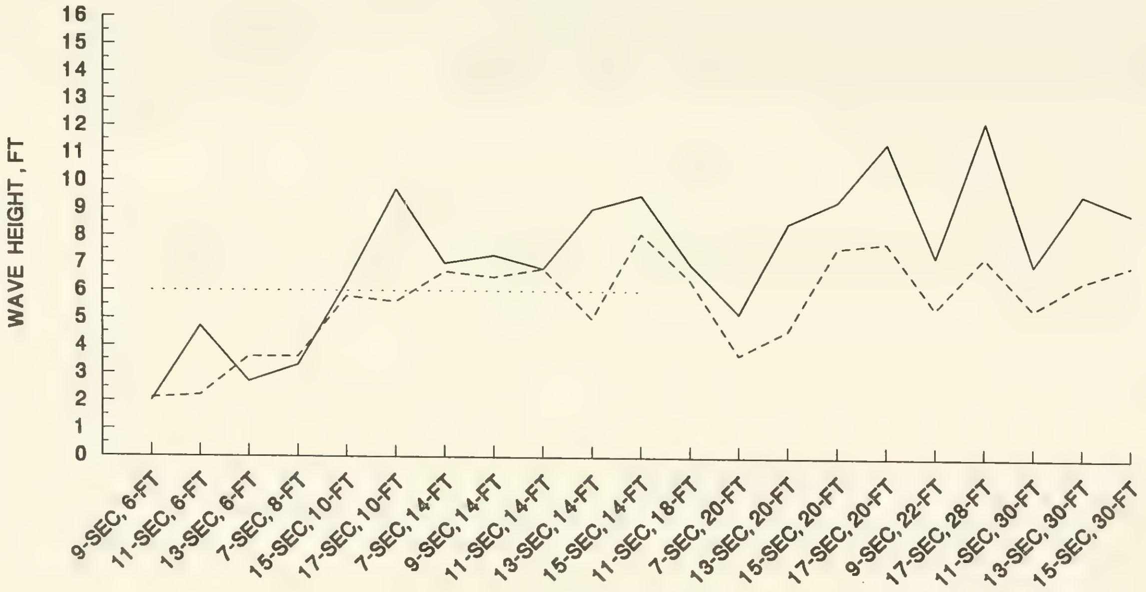
LEGEND

EXISTING CONDITIONS

OFFSHORE BREAKWATER PLAN

WAVE HEIGHT CRITERION

COMPARISON OF MAXIMUM WAVE HEIGHTS IN ENTRANCE CHANNEL FOR EXISTING CONDITIONS AND THE OFFSHORE BREAKWATER PLAN FROM WEST-NORTHWEST, SWL = +7.0 FT



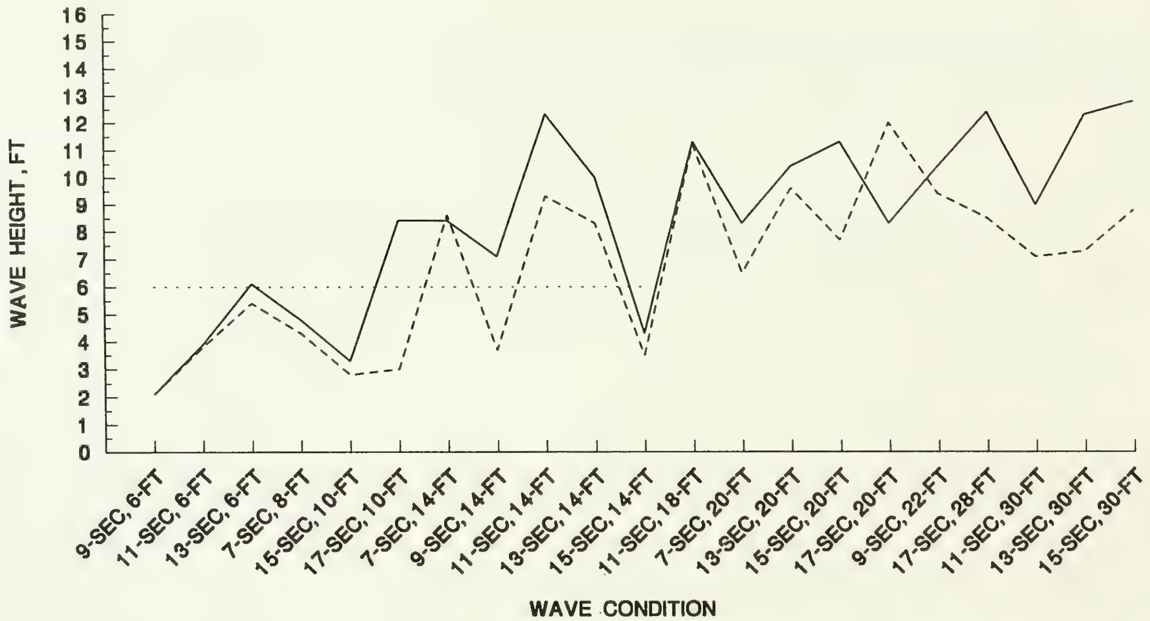
LEGEND

EXISTING CONDITIONS

OFFSHORE BREAKWATER PLAN

WAVE HEIGHT CRITERION

COMPARISON OF MAXIMUM WAVE HEIGHTS IN ENTRANCE CHANNEL FOR EXISTING CONDITIONS AND THE OFFSHORE BREAKWATER PLAN FROM WEST, SWL = 0.0 FT



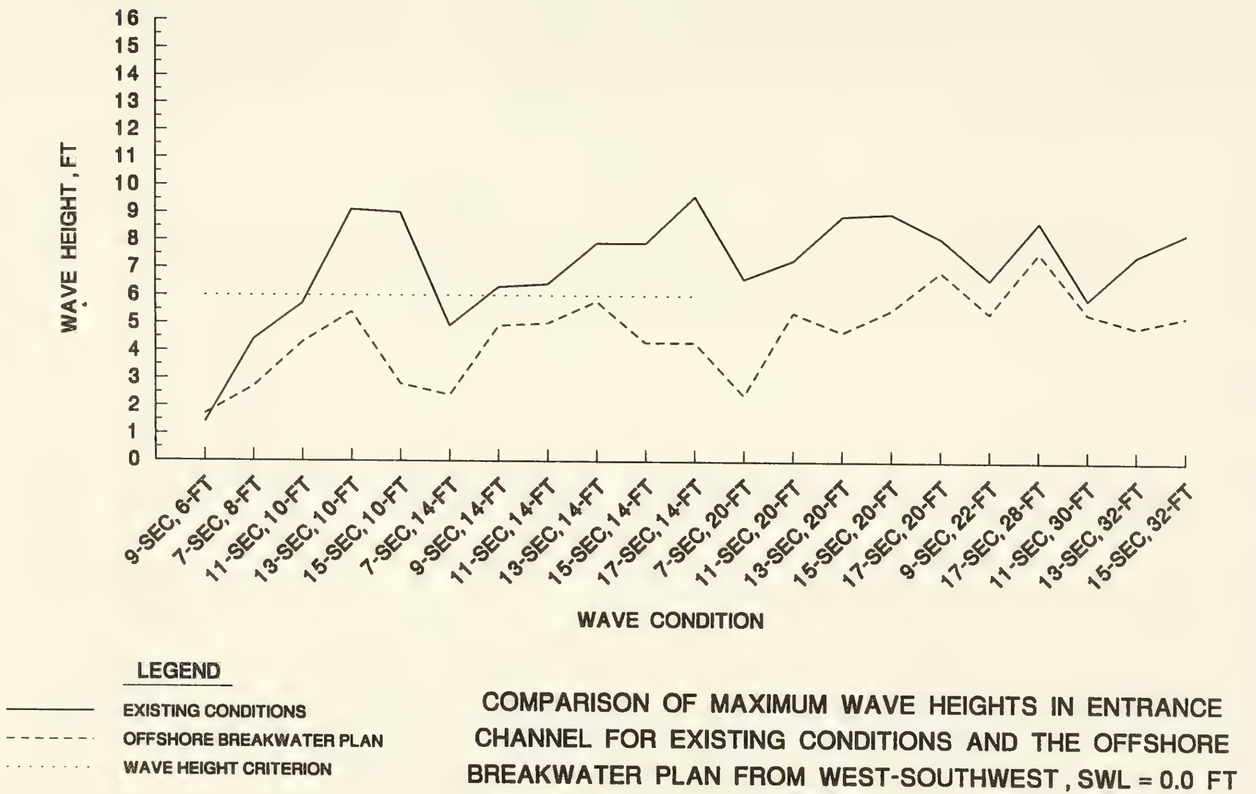
LEGEND

EXISTING CONDITIONS

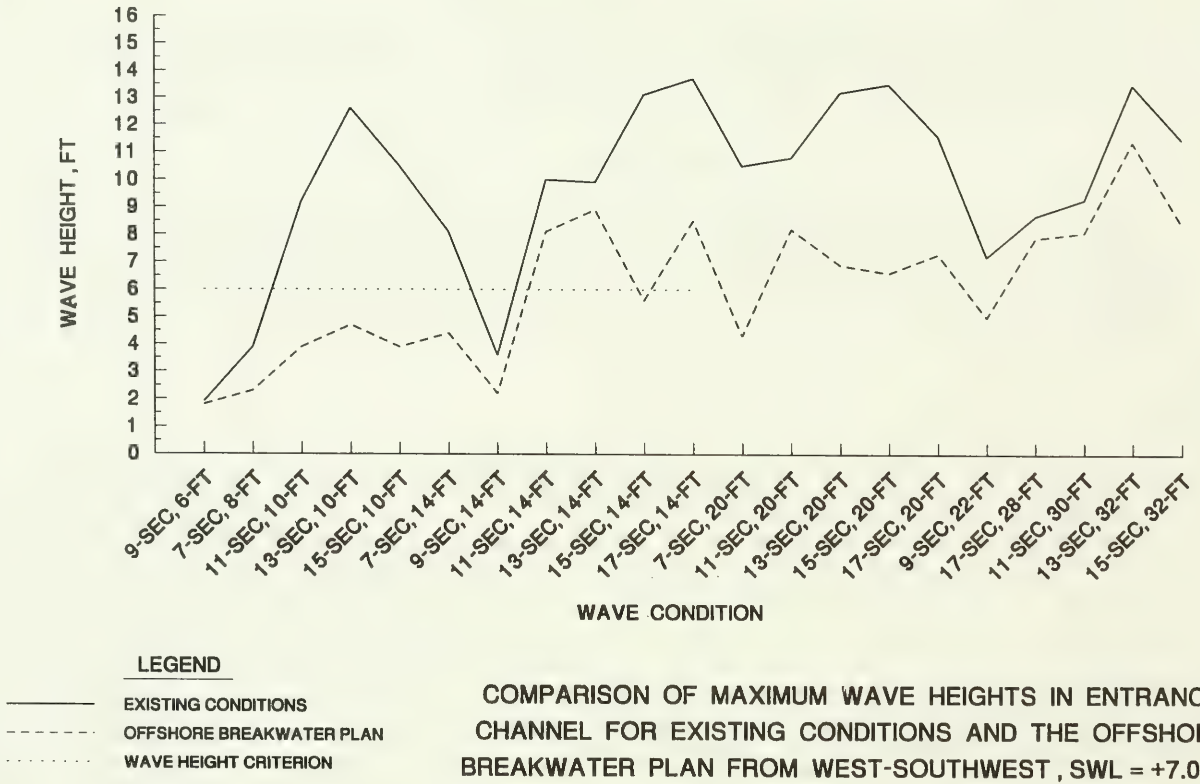
OFFSHORE BREAKWATER PLAN

WAVE HEIGHT CRITERION

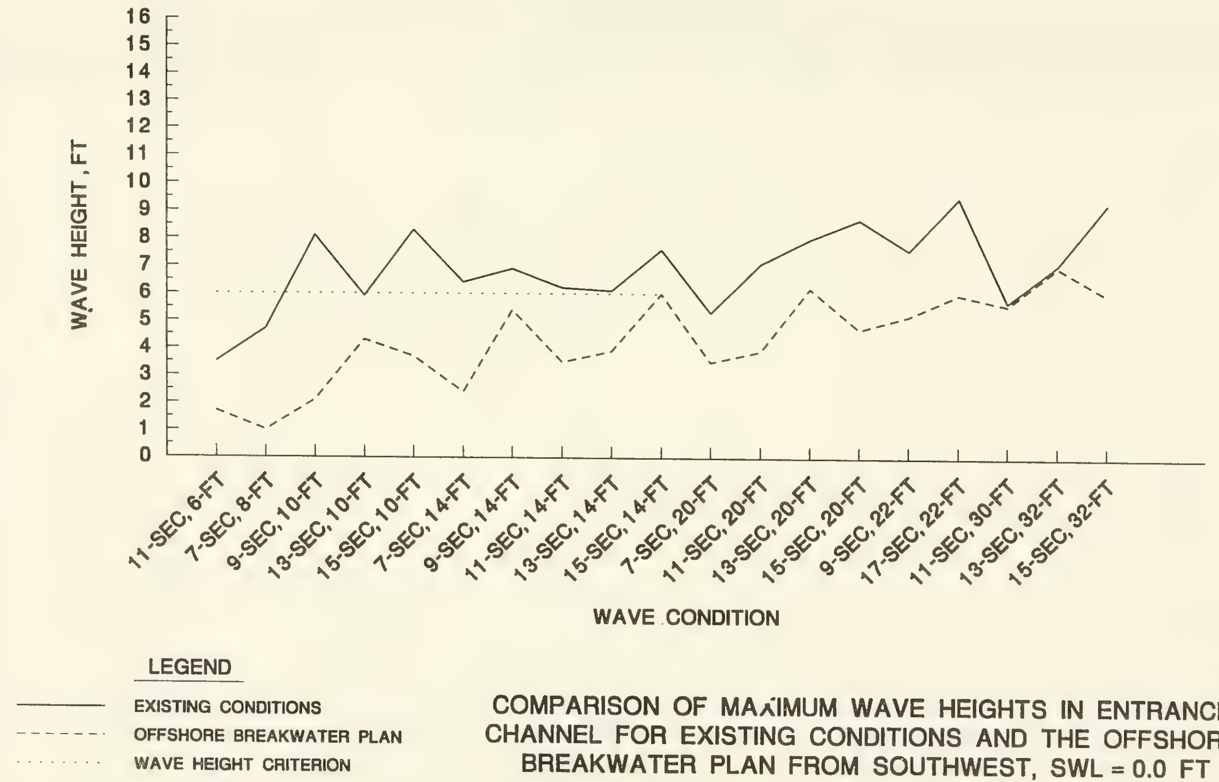
COMPARISON OF MAXIMUM WAVE HEIGHTS IN ENTRANCE CHANNEL FOR EXISTING CONDITIONS AND THE OFFSHORE BREAKWATER PLAN FROM WEST, SWL = +7.0 FT



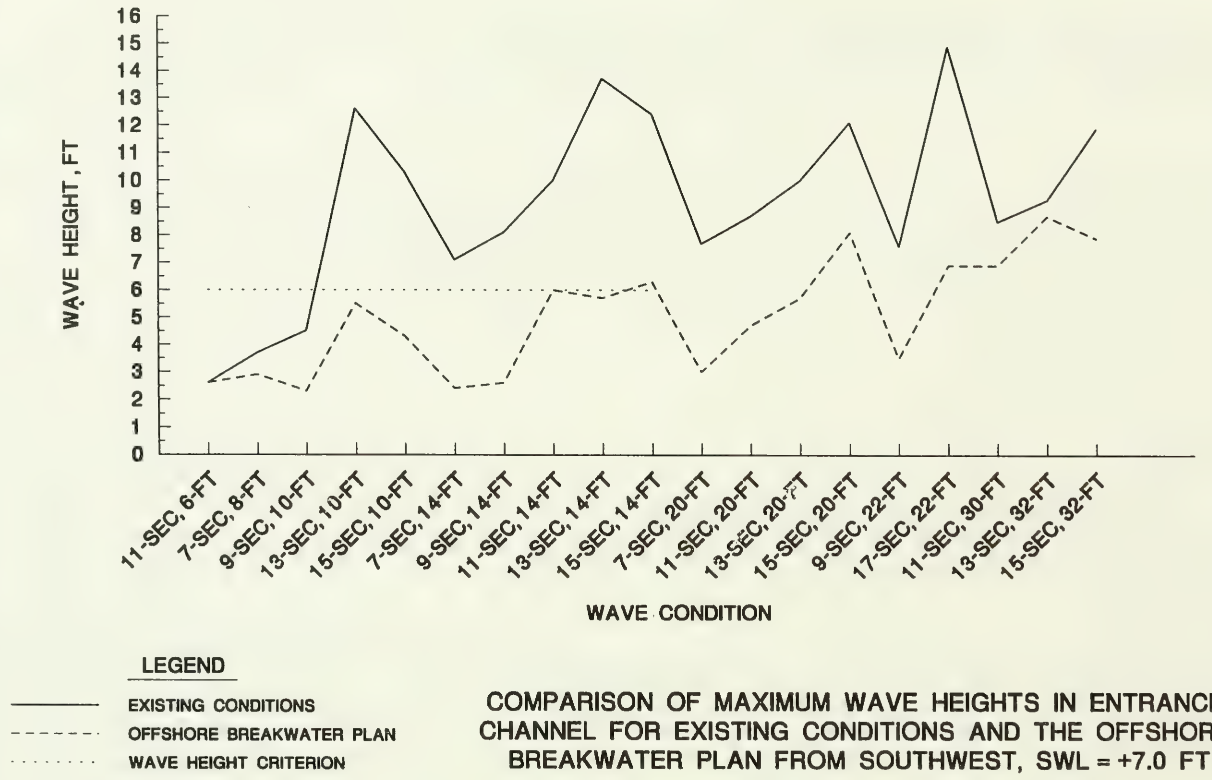
COMPARISON OF MAXIMUM WAVE HEIGHTS IN ENTRANCE CHANNEL FOR EXISTING CONDITIONS AND THE OFFSHORE BREAKWATER PLAN FROM WEST-SOUTHWEST, SWL = 0.0 FT



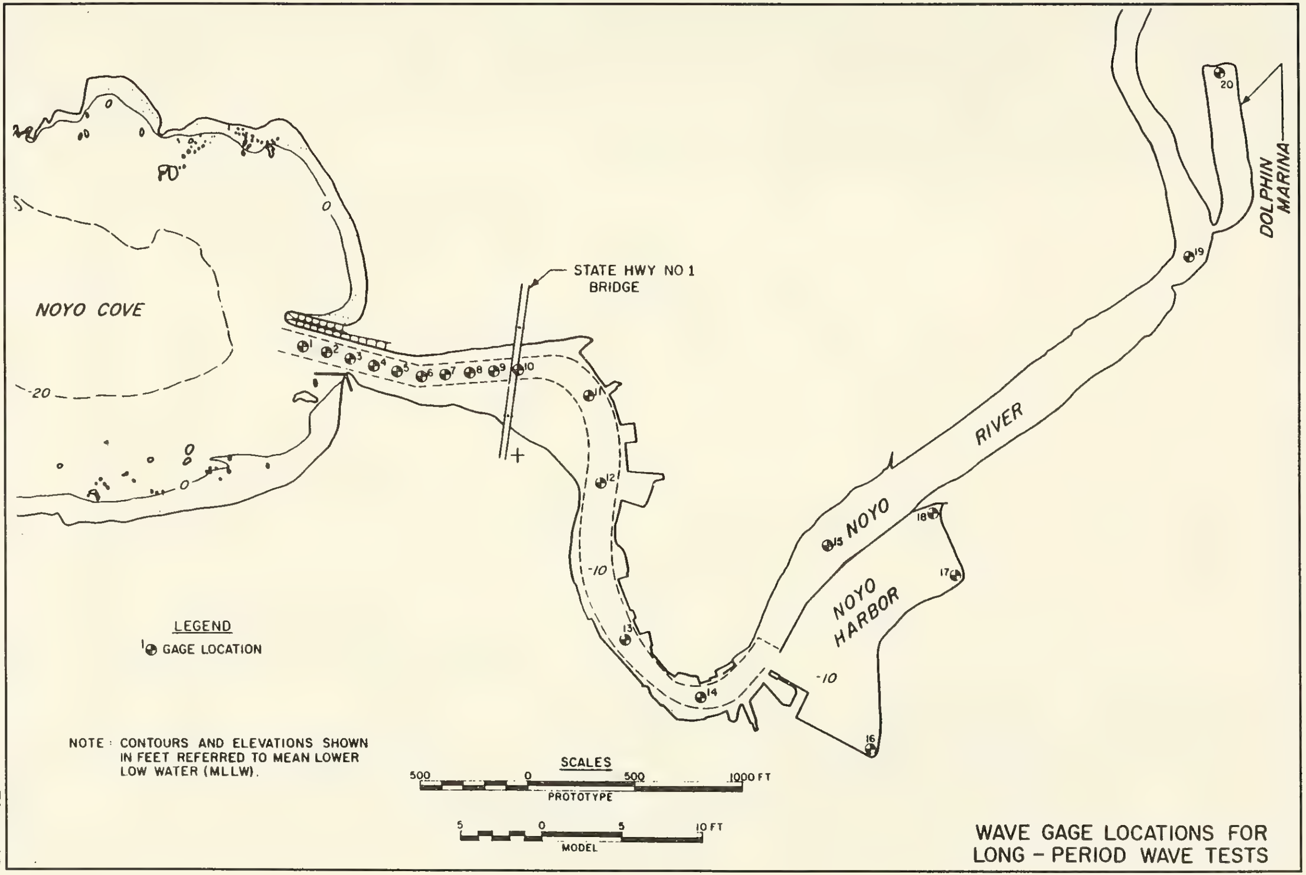
COMPARISON OF MAXIMUM WAVE HEIGHTS IN ENTRANCE CHANNEL FOR EXISTING CONDITIONS AND THE OFFSHORE BREAKWATER PLAN FROM WEST-SOUTHWEST, SWL = +7.0 FT



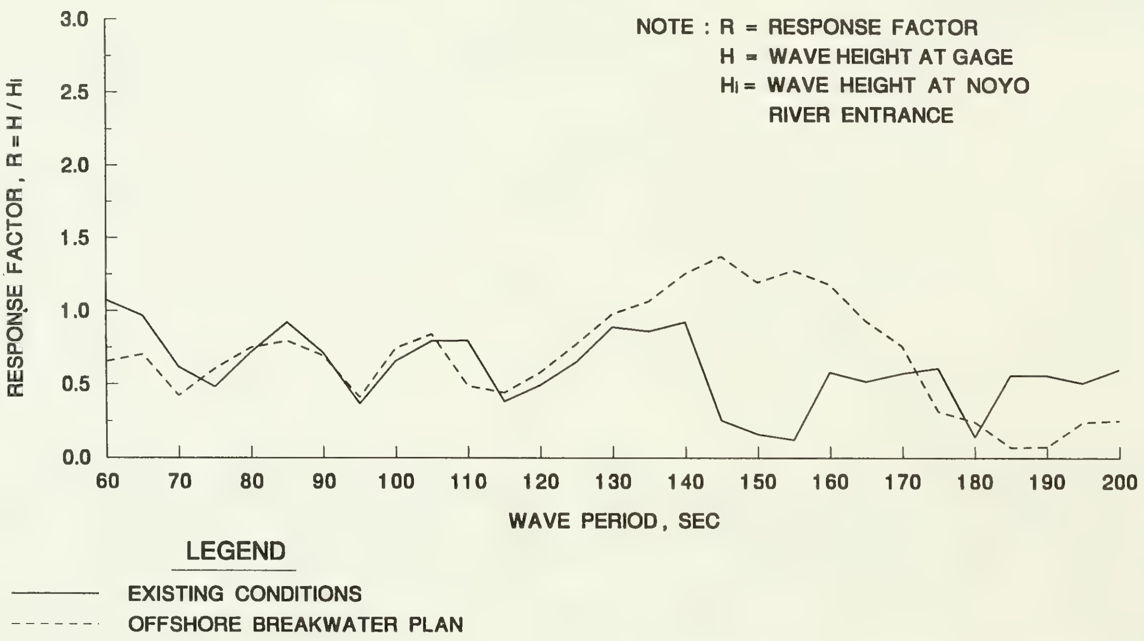
COMPARISON OF MAXIMUM WAVE HEIGHTS IN ENTRANCE CHANNEL FOR EXISTING CONDITIONS AND THE OFFSHORE BREAKWATER PLAN FROM SOUTHWEST, SWL = 0.0 FT



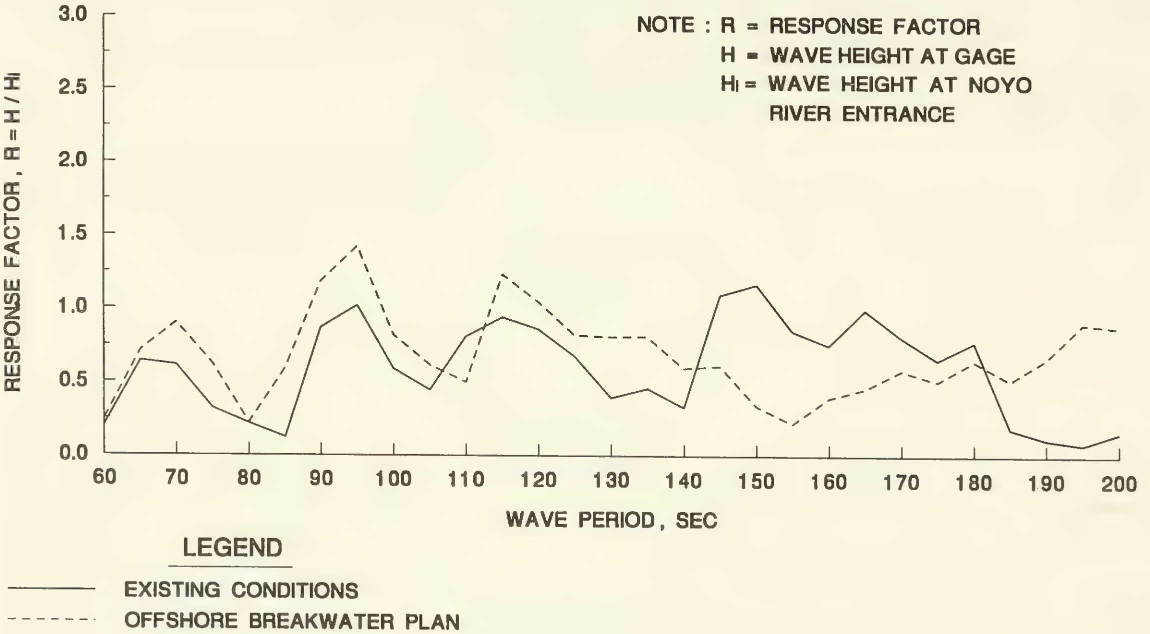
COMPARISON OF MAXIMUM WAVE HEIGHTS IN ENTRANCE CHANNEL FOR EXISTING CONDITIONS AND THE OFFSHORE BREAKWATER PLAN FROM SOUTHWEST, SWL = +7.0 FT



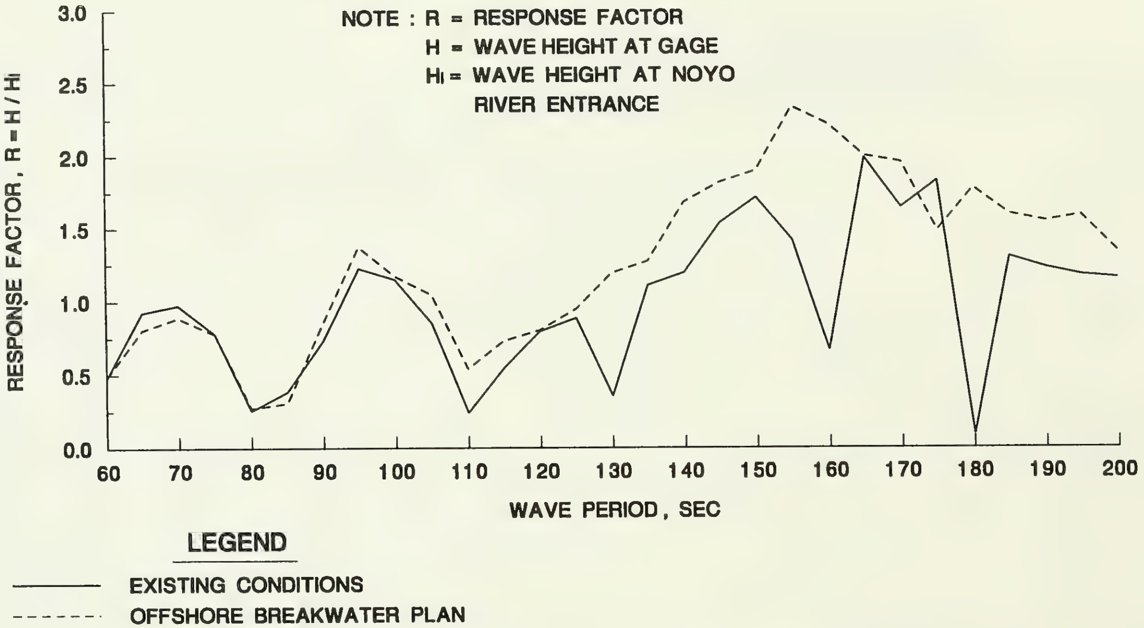
WAVE GAGE LOCATIONS FOR LONG - PERIOD WAVE TESTS



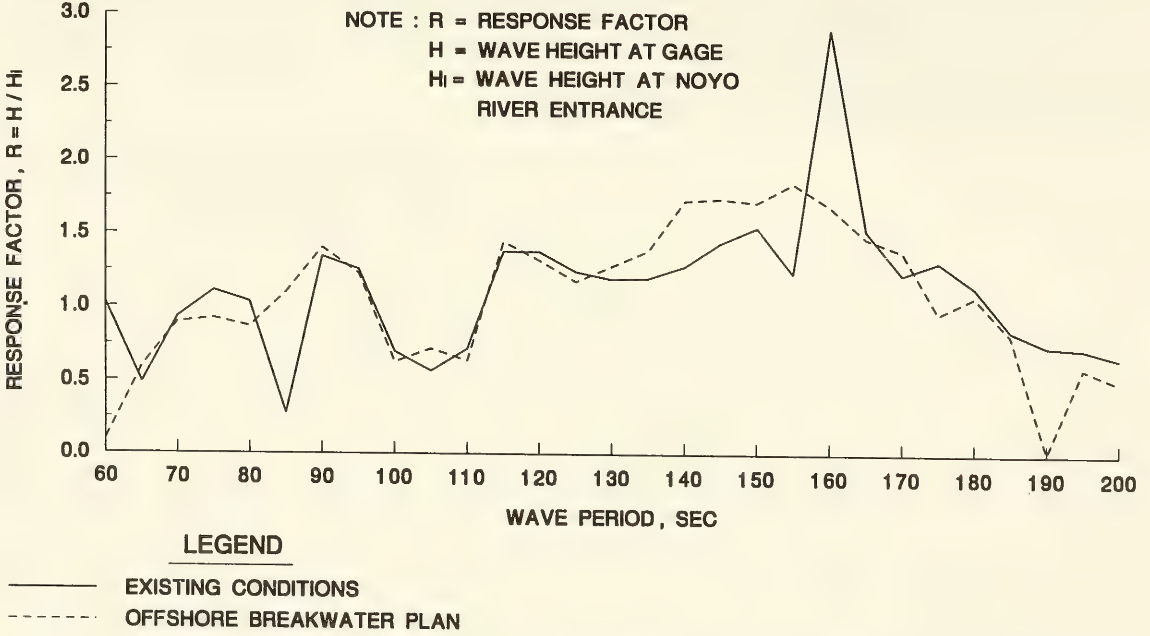
COMPARISON OF FREQUENCY RESPONSE
IN NOYO RIVER
WAVE GAGE 11



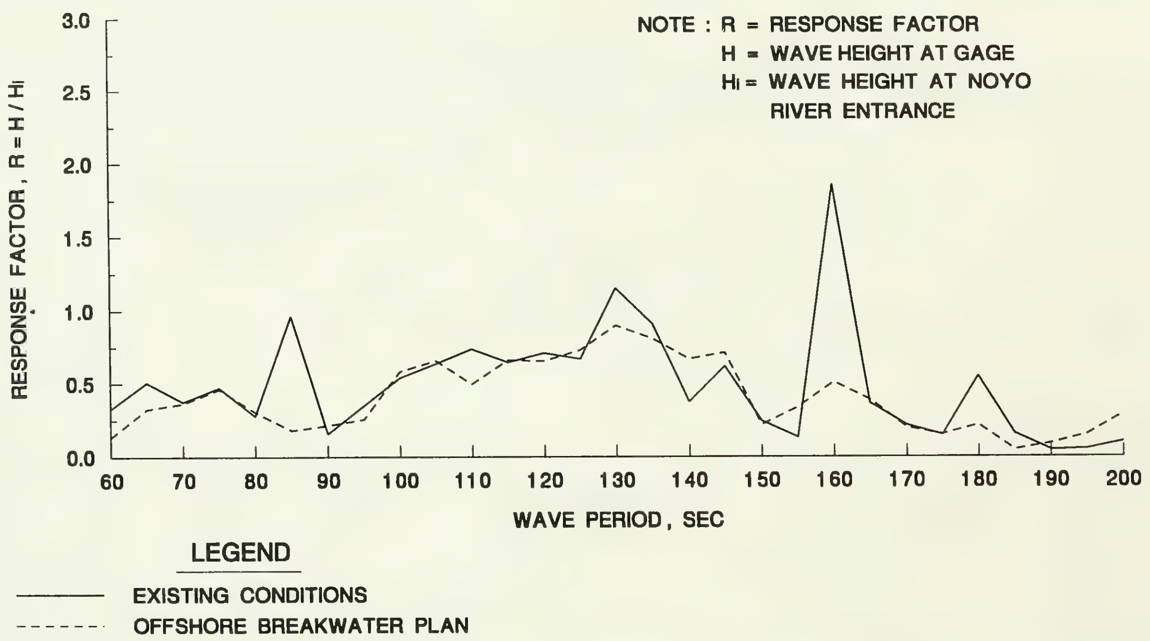
COMPARISON OF FREQUENCY RESPONSE
IN NOYO RIVER
WAVE GAGE 12



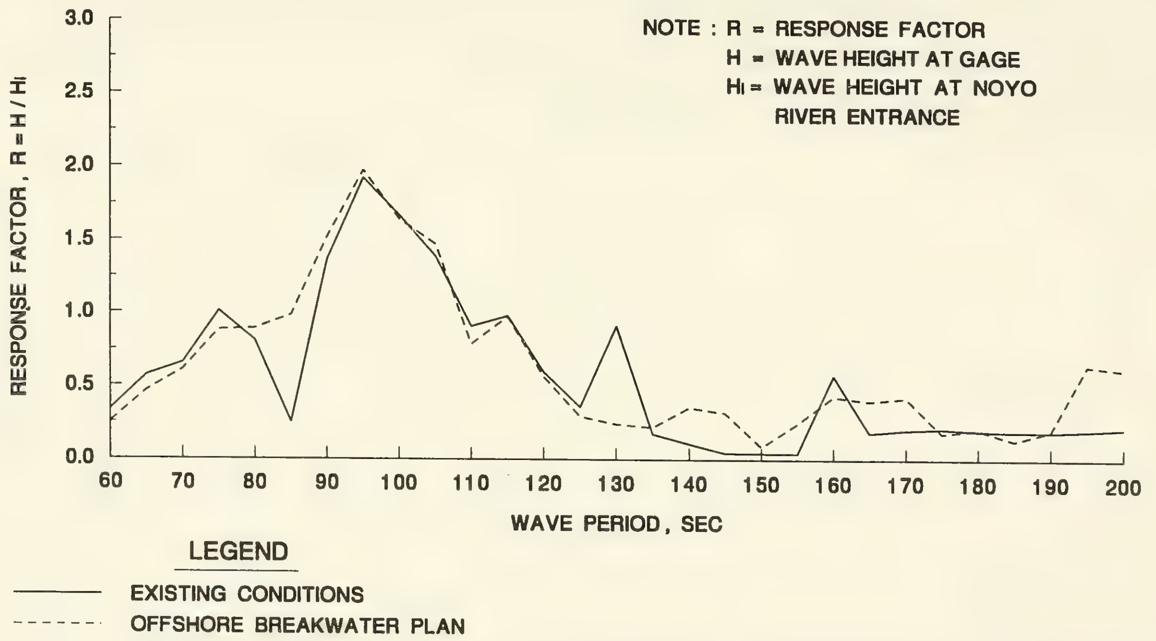
COMPARISON OF FREQUENCY RESPONSE
IN NOYO RIVER
WAVE GAGE 13



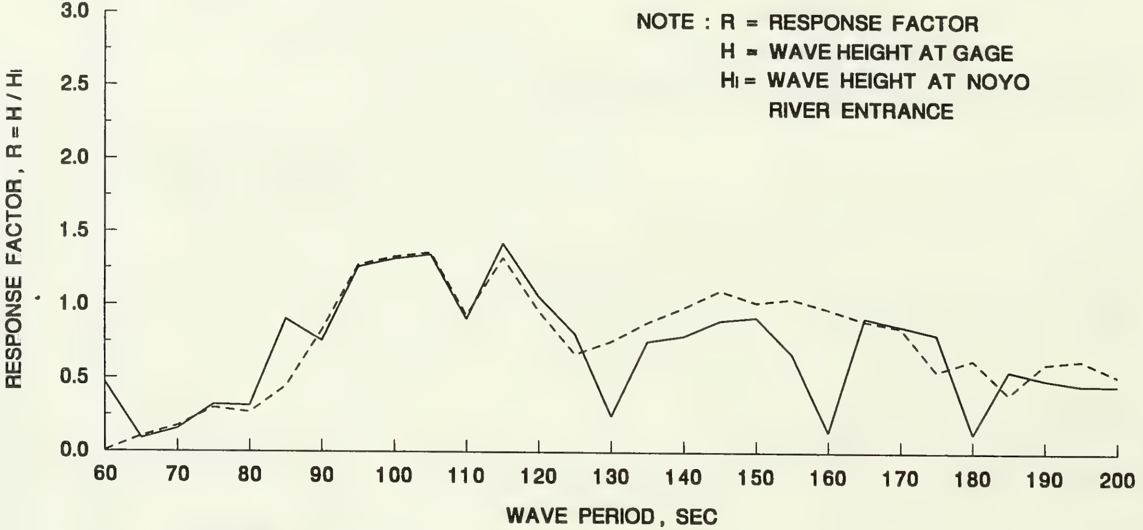
COMPARISON OF FREQUENCY RESPONSE
IN NOYO RIVER
WAVE GAGE 14



COMPARISON OF FREQUENCY RESPONSE
IN NOYO RIVER
WAVE GAGE 15



COMPARISON OF FREQUENCY RESPONSE
IN NOYO HARBOR
WAVE GAGE 16

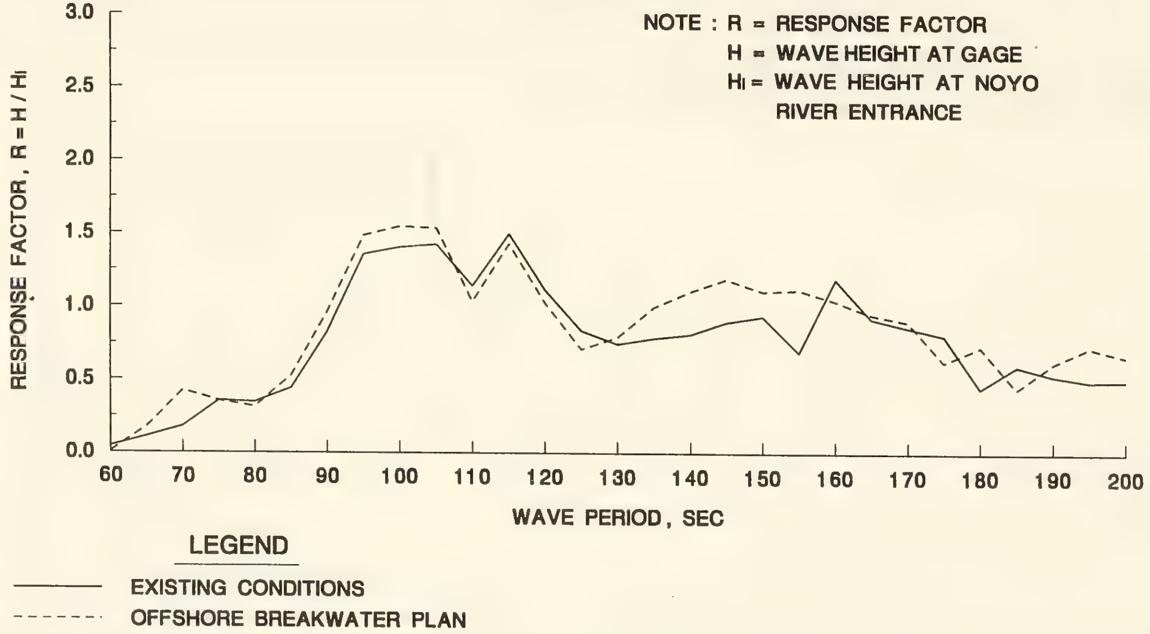


LEGEND

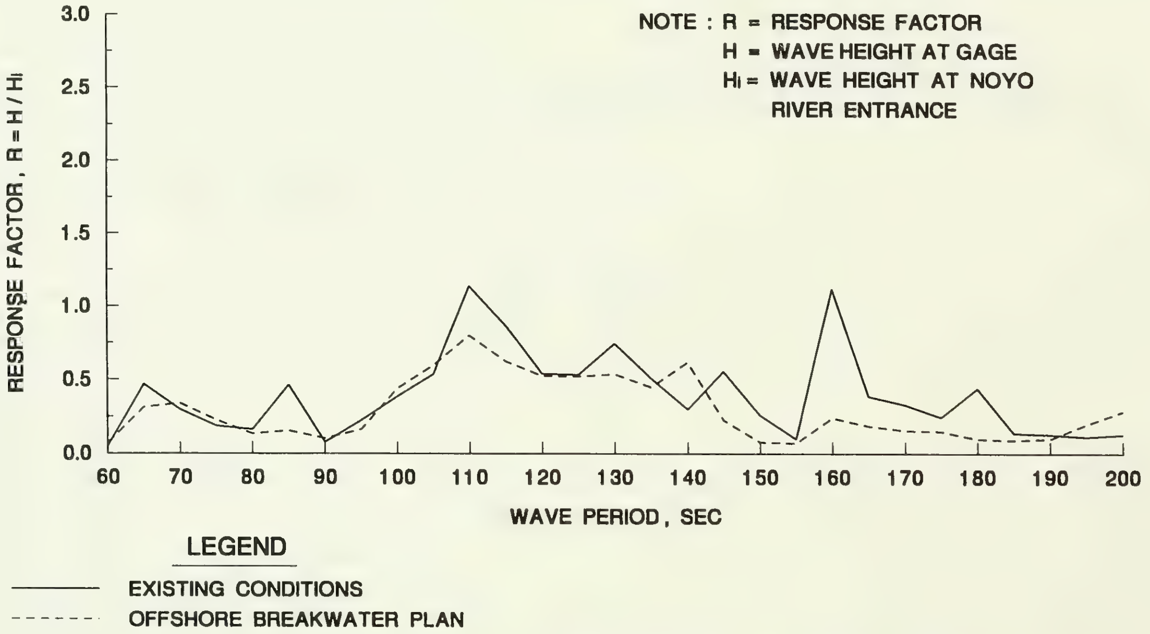
EXISTING CONDITIONS

OFFSHORE BREAKWATER PLAN

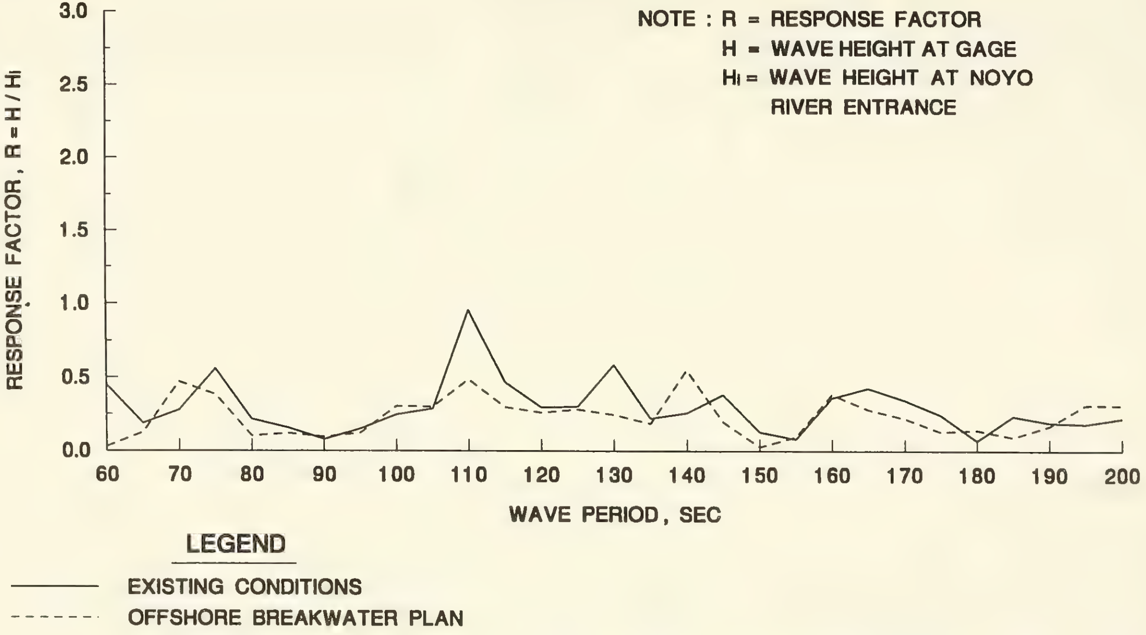
COMPARISON OF FREQUENCY RESPONSE
IN NOYO HARBOR
WAVE GAGE 17



COMPARISON OF FREQUENCY RESPONSE
IN NOYO HARBOR
WAVE GAGE 18



COMPARISON OF FREQUENCY RESPONSE
IN NOYO RIVER
WAVE GAGE 19



COMPARISON OF FREQUENCY RESPONSE
IN DOLPHIN MARINA
WAVE GAGE 20

REPORT DOCUMENTATION PAGE

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13. ABSTRACT *(Maximum 200 words)*

A 1:75-scale undistorted hydraulic model was used to determine wave conditions at the entrance to Noyo River and Harbor as a result of an offshore breakwater. The impact of the improvements on long-period wave conditions in the harbor as well as wave-induced and riverine bed-load sediment patterns was evaluated. The model reproduced the river from its mouth to a point approximately 15,000 ft upstream, both Noyo Harbor and Dolphin Marina located on the south bank, approximately 3,400 ft of the California shoreline on each side of the river mouth, Noyo Cove, and sufficient offshore area in the Pacific Ocean to permit generation of the required test waves. A 45-ft-long wave generator, crushed coal sediment tracer material, and an automated data acquisition and control system were utilized in model operation. It was concluded from the model investigation that:

a. Existing conditions are characterized by rough and turbulent wave conditions in the Noyo River entrance. Maximum wave heights ranged from 8.5 to 13.7 ft in the entrance for operational conditions (incident waves with heights of 14 ft or less) and from 12.2 to 15.2 ft for extreme conditions (waves up to 32 ft in height) depending on incident wave direction.

(Continued)

14. SUBJECT TERMS
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19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

13. (Concluded).

b. The offshore breakwater plan will result in maximum wave heights ranging from 6.3 to 9.3 ft in the entrance for operational wave conditions and 8.7 to 14.6 ft for extreme conditions depending on incident wave direction.

c. The offshore breakwater plan will not meet the 6.0-ft wave height criterion in the entrance for all incident waves of 14 ft or less (operational conditions). Based on hindcast data, however, the breakwater plan will result in the criterion being achieved 37 percent more of the time than it currently is for existing conditions when operational waves are present. The magnitude of wave heights also will be decreased by about 27 percent as a result of the offshore breakwater for operational waves.

d. With no waves present, the offshore breakwater resulted in riverine sediment patterns similar to those obtained for existing conditions except for the 100-year (41,000-cfs) discharge. For this condition, the breakwater prevented material from moving as far seaward in the cove as it did for existing conditions.

e. With waves present from west-northwest and west, the offshore breakwater slightly changes the paths of riverine sediment migration and subsequent deposits for some river discharges and does not for others. In general, considering all test conditions, riverine sediment will deposit in an area in the cove between the existing jettied entrance and the proposed structure location, both with and without the breakwater installed.

f. The offshore breakwater will not interfere with the migration of wave-induced sediment into the cove for waves from northwest; however, for waves from southwest, the breakwater will prevent some sediment from penetrating as deeply shoreward in the cove as it did under existing conditions.

g. The offshore breakwater plan will have no adverse impact on surge conditions due to long-period wave energy in Noyo Harbor, Dolphin Marina, and the lower reaches of the river.

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